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The Institute of Vitreous Enamellers

The Welsh Engineers' and Founders' Association

and

The Foundry Trades' Equipment and Supplies Association

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Industrial Housing

The Departmental Committee on the Construction of Flats for the Working Classes has now made its final Report. We object *ab initio* to the designation of the Committee, as there is an unjustifiable assumption that there is a fundamental difference in the requirements of a particular section of the community. It is obvious that the Report relates to the construction of low-rental flats, and the inclusion of the phrase " working classes " is, to say the least of it, unfortunate. Beyond this criticism and a second one, which has reference to the Committee's ignorance of culinary conditions, we have nothing but praise. A flat should as nearly as possible have the advantages of a detached cottage, whilst eliminating its disadvantages. Sound-proofing has been adequately dealt with in the Report, and it is obvious that full advantage has been taken of expert advice on fire-proofing and general construction, but where the general question of heating has been considered, insufficient recognition has been given to the fact that, where illumination is definitely adequate, there is no need to pander to an innate craze for an open coal fire. There is a statement in the Report—the subject of our second criticism—that stewing is more popular in artisan homes than roasting, but the truth is the reverse, plus the fact that in many districts the art of cooking has degenerated to the use of the frying pan. We believe that stewing should be developed, and this makes the coal fire more attractive than gas and especially electricity. Whilst the Report denies it, communal hot-water supply throughout the year and central heating in the winter should now be within the range of practical politics, whilst for cooking a choice should be given to the tenant of either gas or coal, these being supplemented by a gas-ring. If these fittings be made free from ugliness, there is no reason why they should not be part and parcel of the sitting room. A microscopic kitchen-scullery, in which the housewife has to spend much of her time, plus a sitting room, and oftentimes a second " reception " room, is fundamentally wrong, and conduces to overcrowding by taking in lodgers. A large kitchen-sitting room is, as the Report states, to be preferred. The views of the Committee on central heating are almost certain to be correct on the score of economy, but surely the statement that " it is not so pleasant as the open fire " is old fashioned? Speaking with a background of fifteen years' experience of central heating, we certainly would never envisage living in a house heated solely by coal, gas or electric fires. We specially commend the five conclusions on these subjects of cooking, heating and hot-water services to the foundry industry. As is stated, attempts to combine them are fundamentally wrong—a view we have long held. Recommendations are made with respect to lifts, and their dangers to children enumerated, but we find no reference to a self-locking gate, keys to open which would only be given to responsible grown-ups.

Animal, Mineral or Vegetable

The huge bulk of the raw materials of the foundry industry are of mineral origin, such as pig-iron, coke, limestone, sand and refractories. The fact that a few years ago it began to use products of vegetable origin, such as linseed oil and certain other materials, lends interest to a recent talk to the Textile Institute by Sir Harold Hartley. Pointing out that agriculture now supplies chiefly food and textiles, he asked to what extent agriculture will in future supply the raw materials of industry. We are well aware that supplies of natural raw material in mineral form are not infinite. Indeed, we all know to our cost that they are not. As a consequence there is both a steady deterioration in quality and an increase in cost. Research in part is an attempt to ensure ourselves against the consequences of such deterioration. In using mineral resources we are living, so to speak, on the earth's capital. If we can use agricultural products we are instead living on its interest. We have long been accustomed to the artificial synthesis of certain complex products of vegetable origin. Thus indigo is not now grown because it can be made. To-day synthetic rubber is not only manufactured, but for certain purposes is preferred. Synthetic resins form another case. Even so, agriculture in its broad sense provides 88 per cent. of its output as food, 8 per cent. as textiles and only 4 per cent. goes to other industries. Rayon and leather can now be made artificially. Alcohol from vegetable sources may be the fuel of the future. Henry Ford is cited as a firm believer in using agricultural products in industry, because only by becoming a customer of the farmer can the farmer become a customer for industry. Of such products used in the foundry the chief are linseed oil, molasses, soya bean oil, tung oil and dextrin from maize. The prospect of such closer co-operation between industry and agriculture opens up very far-reaching possibilities and may indeed be the salvation of agriculture as we know it to-day. Does not this also suggest, in making the fullest use of plant products, one way in which the industry may compete with developments of a competitive kind such as plastics, which themselves have a vegetable origin? We are not likely to return to the use of charcoal as fuel, but scientific afforestation would make it unnecessary for a future Queen Elizabeth to forbid its use on grounds of scarcity, and, like its cousin coal, wood pulp is the beginning of much modern industrial activity.

Correspondence

[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]

First Industrial Colour Film

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—A note was published in the last issue of THE FOUNDRY TRADE JOURNAL to the effect that the *United States Steel Corporation* had started the production of a colour motion picture depicting the making of steel in its various mills, which is to be the *first* industrial educational picture to use colour photography.

May I point out that my film, "Workington Hematite Pig-Irons," in natural colour, will be shown at the Foundry Trades' Exhibition which opens next week, and two other films in natural colour, "Templeborough Melting Shop" and "Driving Frodingham Hoesch Piling," are ready but have not yet been shown to the public —Yours, etc.,

A. W. SWAN,
Sales Promotion and Publicity Department.

The United Steel Companies, Limited,
17, Westbourne Road, Sheffield, 10.
September 6, 1937.

Function of Tuyeres in Cupola Control

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—I would refer you to an article, "The Function of Tuyeres in Cupola Operation," by H. V. Crawford, which was published in the issue of THE FOUNDRY TRADE JOURNAL for August 19, 1937, and I should appreciate it if you would permit me to make just a few comments with regard to this Paper.

To many American readers it may not be apparent that Mr. Crawford has written his article almost entirely in reference to the Balanced-Blast cupola, but I think there will be few of your readers who will not immediately connect this up with that particular cupola, in the way in which Mr. Pearce did in his letter published in your issue of August 26.

Many of us are aware that the writer of the article is a very well-known authority on a certain section of cupola practice, and his work in connection with air supply to cupolas has always been valuable and interesting. However, in this particular instance it seems to me a great pity that Mr. Crawford should continue to further his sound principle with regard to air supply at the cost of attacking—in my opinion, most unfairly—a cupola about which he apparently has so little knowledge, as is clearly shown if one reads his Paper.

I might add that I have no axe to grind with regard to the Balanced-Blast cupola, and my interests and enthusiastic support for it arise from the fact that to me, as an actual operator of two such cupolas, the soundness of the system and the material benefits arising from its use, justify my confidence in defending it against an attack of this type. Again, if the cupolas which I operate did not function satisfactorily and economically, I can assure you that the system would be scrapped at once.

However, it may interest your readers to know that one of these cupolas is melting day after day (not alternate days) an amount of metal considerably in excess of 50 tons per day. The mixture used contains 30 per cent. of steel, and since the metal is required for the production of malleable castings, the silicon contained is of the order of only 0.7 per cent. The fact that such metal is melted satisfactorily for the production of very thin castings by a coke ratio of 10.5 to 1 including the bed, and 11.9 to 1 excluding the bed, is sufficient evidence with which to reply to Mr. Crawford's attack.

I might be so bold as to suggest that the author should have held over his article until he had had more practical experience with the Balanced-Blast cupola and had made more inquiries about it, because he would probably then have found that instead of decrying this particular system of melting practice, he could have linked it up very favourably with the particular type of equipment with which Mr. Crawford is vitally interested, especially if he had been able to have informed his readers that, as Mr. Pearce pointed out in his letter, there are several Balanced-Blast cupolas working with automatically-controlled equipment to give a constant weight of oxygen.—Yours, etc.,

H. H. SHEPHERD.

8, Newry Avenue,
Felixstowe, Suffolk.
September 1, 1937.

Properties of Some Special Irons at Elevated Temperatures

In a Paper presented to the International Foundry Congress in Paris, J. CHALLANSONNET makes a comparative study of the thermal stability and mechanical properties when hot of cast irons of the ordinary, and chromium, molybdenum, vanadium, molybdenum-vanadium and nickel-molybdenum-vanadium types.

The lowering of the change point by heating of cast iron due to the presence of chromium is already well known. Molybdenum does not increase the stability of iron carbide in the slightest degree within the compositional limits dealt with by the author. All the irons of the Va, Mo-Va and Ni-Mo-Va types studied have but little influence upon the heating-up change point, which is never greater than that of the chromium cast iron examined at the same time. A Ni-Mo-Va iron showed at the end of prolonged heating a residual expansion eight times less than that of a normal pearlitic cast iron. An ordinary pearlitic iron loses 45 per cent. of its breaking load under static bending when the test is made at 600 deg. C. In the same conditions, the chromium iron loses 35 per cent. of its breaking load, and the molybdenum iron 30 per cent.

The complex Mo-Va and Ni-Mo-Va cast irons with superfine graphite derived from Vantit pig-irons lose 35 per cent. at 600 deg., but they have at this temperature a strength double that measured on an ordinary pearlitic iron at the same temperature. With prolonged application of the temperature of 600 deg. the differences still subsist.

The author has revealed the extremely clear influence of molybdenum on the preservation of hardness at elevated temperatures. With complex Mo-Va and Ni-Mo-Va additions in small quantities it is possible to secure cast irons of which the Brinell hardness at 600 deg. remains of the order of 200.

THE FOUNDRY TRADES' EXHIBITION

Our issue next Thursday will be devoted to a comprehensive description of the plant and machinery shown in the Foundry Exhibition which opens at Olympia that day. Details of the welding section and shorter notes on the materials displayed in the general engineering exhibition will also be given.

Random Shots

"What's in a name?" goes the classical saying. "Too much by far" must be the poor reader's answer who tries to pronounce some of the names of the contributors in the JOURNAL last week. Even the British ones are teazers, but "Czolgos" is nothing short of a sneezer. However, it is all good practice for that promised week in Poland next year, where English foundrymen will have to struggle with names much worse even than Gierdziejewski. One might think out a sort of morse code for that occasion, to cope with the difficulties of the Polish language, consisting of a varying number of sneezes emitted in different keys, and if anyone thinks that "Marksman" is understating its difficulties, let him take a look at the Polish note in the "Trade Talk," also in last week's issue

* * *

A schoolboy once confided to his father that he remembered his lessons by a self-made system of Pelmanism; going something like this: "The capital of Sweden is Stockhome with Oxo in Norway." Father pointed out the dangers of such methods with the story of the man who was asked to call on a certain Mr. Crummock whilst in Glasgow. When he got there he couldn't find Mr. Kelly anywhere.

* * *

Anyone with a grouse should take it to Scotland and shoot it. Now's the time! But one poor Englishman went to Scotland for a holiday without a grouse and brought one back with him (unshot). He stayed the night at a house with no garage, and the landlady charged him 6d. for parking his car in the lane round the corner.

* * *

The foundry industry is shortly expecting an interesting event. Whilst it is only another Exhibition at Olympia, it is hoped that all the fond uncles will call and pay their respects at an early date.

* * *

Talking of "what's on?" brings a reminder of the story told of a lady who, living on a lonely ranch in America, was once reduced to making her clothes from flourbags and sacking. After a busy day's work she found that she had cut out a pair of unmentionables with "The Pride of the Prairie" inscribed on the back.

* * *

There are many manias which beset the man whose fate it is to sit at an office desk. There is the mania for drawing patterns on the blotting paper; for writing monograms on the telephone pad, and there also seems to be an irresistible fascination about the printed form, which somehow or other before the day is over finds itself filled up very facetiously. This is a specimen which "Marksman" managed to slip into his pocket from the table of a prominent foundry manager.

Name of firm: Tanner & Bobs, Unlimited.
Address: Thieves' Kitchen, W.C.2.
Name of Foundry Manager: Fagin.
Name of Superintendent: Bill Sykes.
Name of Metallurgist: Artful Dodger.
Our firm makes castings for ... Own use.
If not engaged in manufacture of castings, state nature of business: Spurious coinage.
Member's name: Charlie Peace.

* * *

"Marksman" would like to know if an artists' model must be taken at bare value or face value?

* * *

Large stocks of ore are reported to be ready for export, says an official communiqué from Salamanca, but there is a shortage of skilled labour. Unfortunately in the present state of uncivil war in Spain all the skilled labour has become killed labour.

"MARKSMAN."

Split Patterns and Pattern Plates

By JAMES TIMBRELL

The author having read the article on "A New Method of Making Pattern Plates,"* which was written by a prominent American foundryman, presented to a German technical society, criticised by a French expert, and duly translated for the benefit of our English-speaking readers, thought the general subject would be advanced by the personal development which is described below.

Fig. 1 shows an arrangement for the accurate marking out of guide lines on pattern plates,

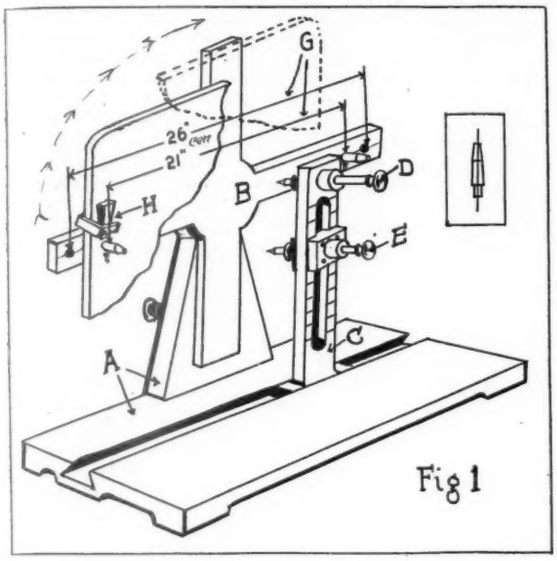


Fig 1

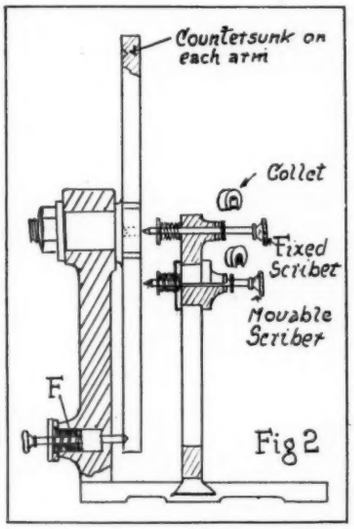
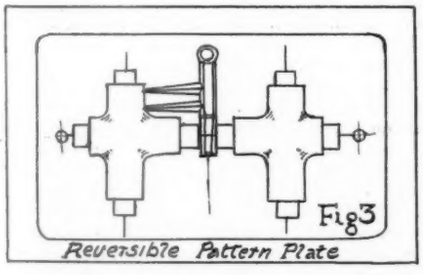


Fig 2

and where quantities justify its adoption, it is quicker than the straight-edge and square method for single reversible or double plates. The apparatus consists of a baseplate and side bracket A, Fig. 1, which carry a turning plate carrier or "spider," B; a slide bracket movable in a V slot C; one fixed spring-loaded scriber D; and one movable spring-loaded scriber in the vertical slot E.

The fixed scriber D is set true to the pin centre-line in the revolving plate "spider," which has a countersunk hole at an equal distance from the centre in each of the four arms. These engage in turn with a spring-loaded stop

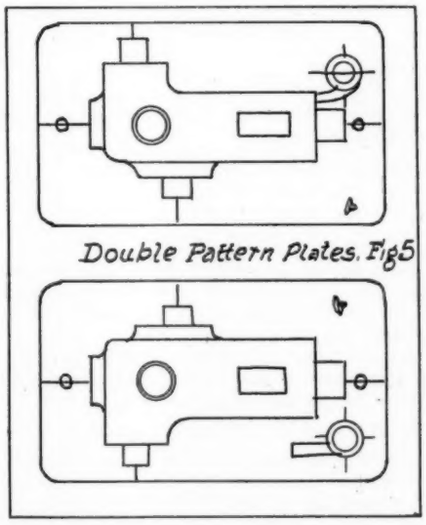


(shown at F, Fig. 2). The plate carrier pins and centres may be set to take various size pattern plates.

For the purpose of this article, and to simplify the description, two sizes of pattern plates have been adopted, 21 in. and 26 in. centres respectively, with ¾ in. pins in each case. A 21 in. centre plate is shown (in part) held to the face by a clamp. The collet is taken out of the fixed centre line scriber, and the slide C is moved across the base, giving a parallel line true to pin centres. The collet is replaced on the fixed scriber, and the spider given a quarter turn until the countersunk hole engages with the stop.

The sliding collar, which carries the scriber E, is moved up or down to the required position, the collet removed, and the slide moved across the face of the plate. The collet is replaced, and the sliding collar left in the exact position. The spider is then given a half turn to engage with the stop, and the collet is taken out. If the slide is moved across the face, it will give a line true to the previous one in relation to the pins.

The three lines shown on the plate will be the positions which the two half patterns will occupy when the marks register on the lines. A simple pattern (Fig. 4) is illustrated, and the inset

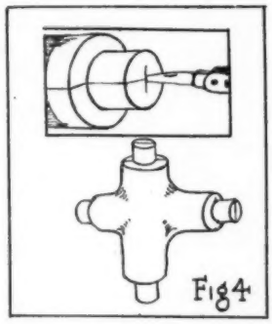


shows an easy method of marking a pattern before removing the dowels.

Attaching the patterns as shown in Fig. 3 makes the pattern plate reversible, and from it top and bottom moulds can be made. In this case, the runner can be fixed on the centre line (Fig. 3), and should be brought beyond the opposite line. On closing the moulds, the bar will cover itself and two inlet gates will be attached to each casting.

Fig. 5 shows double pattern plates marked out by the same method. The pattern is marked out by the method illustrated in Fig. 4, and one half laid on the pattern plate to note its likely position, then the plate is placed on the spider and marked out, and the other plate marked off to give the same mating lines. The half-patterns are then placed in their respective positions and attached in the usual way.

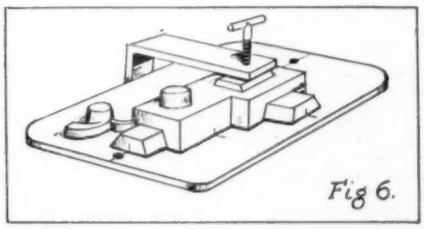
Runner position lines can be marked off in the same way, and will register to each other on closing. Any castings which show cross-joint from patterns set up by this apparatus when properly fitted up, narrow down the investigation to either worn closing pins or holes, as marking-out errors cannot be made if reasonable care is taken when in use. A small amount of taper may be given on the master pins (see inset



in Fig. 1). This taper will take up the wear space on worn pattern plate pin holes.

To prove the fixed scriber line at any time, a line should be made on a plate and the spider given a half turn to engage with the stop, and the line repeated. This second line should superimpose on the first, and any overlap should be rectified or cross-jointed castings will result.

Glue was mentioned in the article referred to as a suitable medium for sticking patterns to plates, but holding in place with a clamp and fastening with screws is definitely preferable, as shown in Fig. 6. Where sticking is deemed essential, the following method is to be commended. Shellac varnish is well spread on the pattern joint face; used plaster or chalk is scraped liberally on to this and the patterns are rubbed in a circular motion on to the pattern plate. It should be brought to rest with the marks at the register on the lines, and then left for a while. This method will withstand the



usual foundry rapping during use, providing, of course, the pattern joint face is level and clean and the plate is free from rust. The most serious drawback to the use of shellac fastening is that the patterns are hard to remove, and, on levering off, they tend to tear the grain of the wood.

The British Oxygen Company, Limited, has acquired a controlling share interest in the Odda Smeltewerke, A/S, of Norway, which is said to be the largest manufacturer of carbide imported into Britain.

* Foundry Trade Journal, August 19, pp. 141-142.

Notes on the Light Foundry Alloy A.P.33*

By J. CASTEL

It is known that the aluminium-copper alloys containing 4 to 8 per cent. of copper employed at present for foundry purposes may be improved by heat-treatment. This improvement is conditioned by a structural modification which is never complete even with very prolonged treatment (several days); it is, therefore, not always easily effected in industrial practice.

Dr. Pacz found that a small addition of titanium added under certain special conditions markedly improved the coarse crystalline structure of the copper-bearing light alloys, enabling fully efficacious use to be made of the heat-treatment process, and at the same time reducing its duration to a matter of some hours. In this way a foundry alloy exhibiting superior mechanical properties is obtained. Dr. Pacz obtained a tensile strength of 19 tons per sq. in. with 4 per cent. elongation on a sand-cast test-piece heat-treated under these conditions. The alloy referred to by Dr. Pacz was relatively easy to prepare in the laboratory, employing a crucible and making up only small quantities, but under industrial conditions matters were not quite so simple. The problem to be solved was the production on a large scale of ingots which would regularly reproduce the mechanical properties claimed for the alloy, after remelting in the foundry according to some simple technique. This problem was solved and the original results surpassed, in so far as test-pieces cast in green sand from a remelted alloy produced in a large capacity furnace, showed in the heat-treated state tensile values of 20 to 23.5 tons per sq. in., with elongations of 6 to 10 per cent.

A.P.33, therefore, represents an important advance in respect of current copper-bearing alloys, and permits some interesting applications; in many cases where it was desirable to employ a lighter material, and at the same time maintain the strength of the component concerned, this alloy, of specific gravity 2.78, has been able to replace castings in steel. It is sufficient to recall the important part played by A.P.33 in locomotive and automobile construction, in railway work, armaments, field telephone equipment, and in a variety of components employed in the engineering industry.

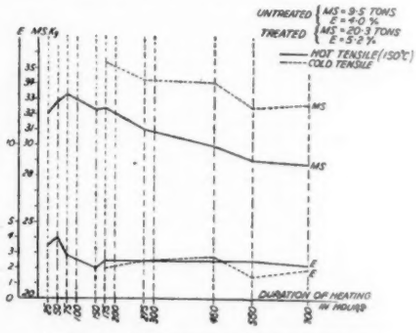


FIG. 1.—MECHANICAL PROPERTIES OF A.P.33 WHEN HEATED TO 150 DEG. C.

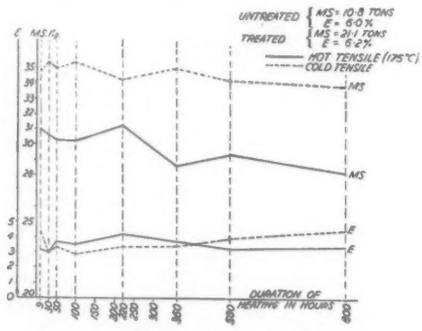


FIG. 2.—MECHANICAL PROPERTIES OF A.P.33 WHEN HEATED TO 175 DEG. C.

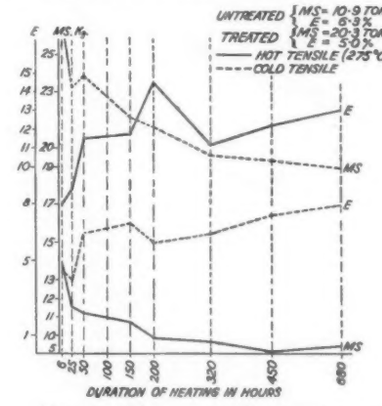


FIG. 3.—MECHANICAL PROPERTIES OF A.P.33 WHEN HEATED TO 275 DEG. C.

Principal Mechanical Characteristics of A.P.33

The results given below were obtained on heat-treated sand-cast test-pieces.

Tensile Strength. — Test-pieces 18 mm. dia., cast in green-sand, and machined to 13.8 mm. dia.

1. *Without heat-treatment.*

Elastic limit (0.02 per cent. proof stress): El. 1 = 2.5 to 3.1 tons per sq. in.

Elastic limit (0.2 per cent. proof stress): El. 2 = 4.5 to 5.7 tons per sq. in.

Ultimate strength: M.S. = 9.5 to 11.4 per sq. in.

Elongation (on 100 mm.): E = 4 to 8 per cent.

Brinell hardness: △ = 50 to 60.

2. *Quenched but untempered.*

Elastic limit (0.02 per cent. proof stress): El. 1 = 6.5 to 7.6 tons per sq. in.

Elastic limit (0.2 per cent. proof stress): El. 2 = 9.5 to 11.4 tons per sq. in.

Ultimate strength: M.S. = 15.8 to 19 tons per sq. in.

Elongation (on 100 mm.): E = 12 to 16 per cent.

Brinell hardness: △ = 80 to 95.

3. *Quenched and tempered.*

Elastic limit (0.2 per cent. proof stress): El. 1 = 9.5 to 11.4 tons per sq. in.

Elastic limit (0.2 per cent. proof stress): El. 2 = 11.4 to 13.9 tons per sq. in.

Ultimate strength: M.S. = 20.3 to 22.8 tons per sq. in.

Elongation (on 100 mm.): E = 5 to 10 per cent.

Brinell hardness (10:1,000:30): △ = 90 to 110.

Fatigue Test.—The fatigue limit was determined by rotary bending on an Alkan machine. 100×10^6 alterations were considered to give the required result.

1. *Quenched but untempered.*

Approximately 4.7 tons per sq. in.

2. *Quenched and tempered.*

Approximately 4.7 to 5 tons per sq. in.

For purposes of comparison it may be noted that the ordinary grade of Alpax gives, under the same conditions, a fatigue limit of 2.8 to 3.5 tons per sq. in.

Impact Test.—Impact values were determined on test-pieces of the Mesnager type, employing a 5 kg. m. Amsler machine.

1. *Quenched but untempered.*

1.0-1.5 kg. m./cm.².

2. *Quenched and tempered.*

1.0-1.5 kg. m./cm.².

Resistance to Repeated Impact.—Determined on a Cambridge machine (falling load = 2 kg. 400; speed = 60 blows per min.; test-piece notched, no radius).

Quenched and tempered.—Drop of 20 mm.—fracture at 360 blows.

Drop of 10 mm.—Fracture at 6,000 blows.

Drop of 5 mm.—Fracture at 220,000 blows.

Hot Tensile Strength

In order to study the tensile properties of the alloy at elevated temperatures, a certain number of test-pieces, all prepared from the same cast, were given the standard heat-treatment (soaked at 530 deg. C., four hours; water quenched; tempered at 150 deg. C., eight hours). Some of the specimens were tested, the remainder being subjected to further heating up to periods of 800 hrs., at constant temperature. The tests were repeated for a range of annealing temperatures between 150 and 275 deg. C. Test-pieces were broken hot and cold.

Annealed at 150 deg. C. and 175 deg. C. for approximately 800 hours.—Cold tensile tests indicated an ultimate strength somewhat superior to that obtained by the normal heat-treatment, but elongation fell rapidly to about 60 per cent. of the usual figure. Hot tensile tests showed a value of about 90 per cent. of the normal cold ultimate strength, after prolonged heating for 700-800 hours. Elongation values were maintained at about 60 per cent. of the normal figure.

Annealed above 200 deg. C.—With heating temperatures above 200 deg. C., the hot and cold tensile strengths diminished progressively, but the elongation values showed appreciable increase.

The graphs, Figs. 1-3, indicate the variations in tensile strength and elongation as functions of the duration of annealing.

Chemical Composition

A.P.33 contains about 4.5 per cent. of copper and 0.25 per cent. of titanium, the balance being aluminium with the normal impurities (silicon and iron).

The optimum copper content is approximately 4.60 per cent., but variations of ± 0.35 per cent. have no ill-effect. Too high a copper content, however, decreases elongation and tensile strength and increases hardness.

The optimum titanium figure is 0.25 per cent., approximately, but it is essential to introduce this quantity into the bath in such a form that it passes entirely and at once into solid solution without the necessity of heating the metal above 750 to 760 deg. C.; the troubles caused by superheating are then avoided. There are numerous ways of introducing the titanium, but the best and most regular results have been obtained by using the Al/Cu/Ti stock-alloy, the manufacture of which has been developed along special lines and has been carefully investigated.

The Influence of Iron and Silicon (Figs. 4 and 5)

The influence of iron has been determined by investigating the mechanical properties of alloys containing increasing quantities of the impurity, up to approximately 1.25 per cent., and by metallographic study of such alloys. It has been shown that in the untreated state the alloys do not undergo more than a slight decrease in tensile strength and elongation, with increasing amounts of iron up to the limit indicated above;

* A Paper presented to the Paris Foundry Congress.

in the fully heat-treated state the tensile strength is to all intents and purposes maintained up to 0.45 per cent. of iron, but beyond this point falls rapidly, until at 1.15 per cent. the properties have so far been affected as to be equivalent to those of the untreated metal; in other words, the value of the heat-treatment process is entirely negatived.

Metallographic studies confirm these findings, and have demonstrated that, with increasing iron contents, increasing quantities of an acicular constituent make their appearance in the $CuAl_2$ network from which they are not removed by heat-treatment.

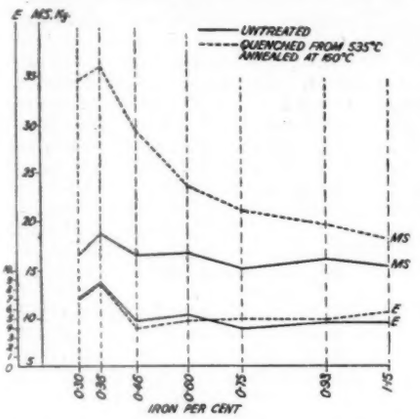


FIG. 4.—INFLUENCE OF IRON ON THE MECHANICAL PROPERTIES OF A.P.33.

The effect of silicon has been determined up to approximately 1.25 per cent. in a manner similar to that employed for iron. In the untreated state, increasing silicon contents up to 1.25 per cent. have no appreciable effect on tensile strength, but cause a progressive decrease in elongation; in the heat-treated state normal properties persist up to 0.60-0.70 per cent. of silicon, above which point the alloy will not withstand the quenching heat required and indications of superheating become apparent. It is known that copper and aluminium form with silicon a ternary compound, the eutectic of which melts at about 525 deg. C.

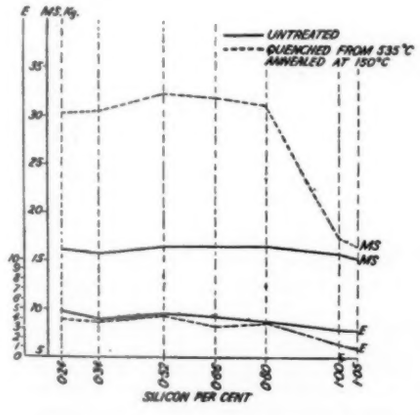


FIG. 5.—INFLUENCE OF SILICON ON THE MECHANICAL PROPERTIES OF A.P.33.

It is concluded, therefore, that it is essential to keep the iron and silicon contents as low as possible; this is generally recognised in practice, and may be effected by employing as raw material a high purity aluminium—99.6 per cent. for example—this enabling both impurities to be maintained at levels below those indicated. In the case of iron special care is required owing to the possible augmentation which may occur during the successive remeltings to which the alloy is normally subjected.

Heat-Treatment of A.P.33

The full potentialities of A.P.33 are only realised in the heat-treated alloy. A simple quenching treatment alone may be employed, but optimum properties can only be obtained by quenching and annealing. In its raw state the alloy consists of a $CuAl_2$ network and a solid solution. Thermal analysis has fixed the liquidus at about 650 deg. C., and the solidus at about 542 deg. C. The quenching heat should, in theory, approach as near as possible to the latter temperature, but in industrial practice it is necessary to provide some margin of safety to guard against superheating on the one hand and incomplete treatment on the other.

Experiments have shown that transformations in the solid state are relatively rapid, but are considerably more influenced by the temperature of heating than the duration of heating. Thus in adopting a standard treatment time of 5 hrs. it may be shown that the transformations have barely begun at 490 deg. C., while at 510 deg. C. they are practically finished.

On the other hand, transformations in the region of the solidus exhibit a certain inertia. Test-pieces heated for five hours at 550 to 555 deg. C. showed no traces of superheating and gave excellent mechanical properties. These are shown in Fig. 6.

It appears desirable from these investigations to employ temperatures of 530 to 535 deg. C. for the quenching heat, thus leaving a margin of ±15 deg. C., which, in practice, should be satisfactory. At temperatures of this order, transformations are active and are completed after about 3 hours' heating. It is to be understood, however, that the heating period may be prolonged with no ill-effects, and, indeed, in the case of large castings must necessarily be increased. The annealing treatment may be carried out according to the particular properties required; a low temperature anneal is conducive to a high elongation, while extreme annealing treatments raise the tensile strength but decrease elongation. Normally 8 hours at 140 deg. C. is recommended.

Melting Practice

Precautions to be observed in melting and casting the metal do not differ widely from those recommended for other light alloys of aluminium. Contact of gases and vapours with the molten metal should be avoided, and all overheating, local or otherwise, should be guarded against.

The choice of a suitable furnace thus becomes important. It must be recalled that gas may be absorbed by the bath not only at the surface but also through the walls of the crucible which become quite permeable at red heat. Pot furnaces fired with dry coke, or rapid heating electric furnaces, give good results. If these precautions are not observed, the metal, which is often remelted many times, rapidly deteriorates, and a coarse crystalline structure and impoverished mechanical properties are obtained. It must be admitted that it is not always easy to ensure in the foundry the observance of even the most elementary precautions, and it appeared absolutely necessary to discover some simple and economical method which would make certain that the alloy always gave the requisite results even after repeated melting under unfavourable conditions. This aim was realised by the introduction into the bath at each remelting of a regenerator.

Regeneration of the Metal

Perfect regeneration of the metal is obtained by introducing into the bath a purifying flux with a titanium fluoride base, in the form of the double sodium-titanium fluoride. The flux is introduced at 720 deg. C. at the rate of three parts per thousand by weight. The evolution of fluorine and the formation of nascent titanium produce a very obvious refining action, and in this manner a fine grained metal with characteristics equal to those of a new cast are always obtained. This process permits of the simple recovery of scrap, runners, risers, etc., produced in the foundry—an important feature from the economic standpoint.

Casting Technique

The alloy commences to solidify at about 650 deg. C., and is completely frozen at approximately 542 deg. C. The contraction is about 14.5 per cent. linear. A.P.33 presents no particular difficulties in casting. It is a little more sensitive than the higher silicon alloys such as Alpax, and resembles in this respect other alloys such as "Y" Alloy, and those containing 4 to 8 per cent. of copper.

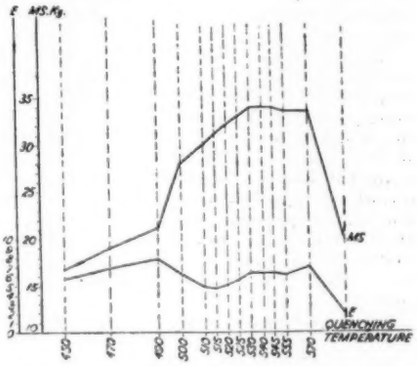


FIG. 6. MECHANICAL PROPERTIES OF TEST-PIECES HEATED TO DIFFERENT TEMPERATURES. ANNEALED AT 140 DEG. C. FOR 8 HRS.

The large freezing range of A.P.33 and its mechanical weakness in the heated condition render it liable to hot-tears and cracking. These dangers may be obviated by the provision of numerous large risers which ensure perfect feeding. Stresses may be reduced by the provision of radii at thick and thin sections, and ribs may be used for reinforcing. Collaboration between the foundry and the research department will assist considerably in the production of sound castings. A.P.33 is cast in green sand or in dry sand; it cannot be cast in permanent moulds except in the case of small or simple components.

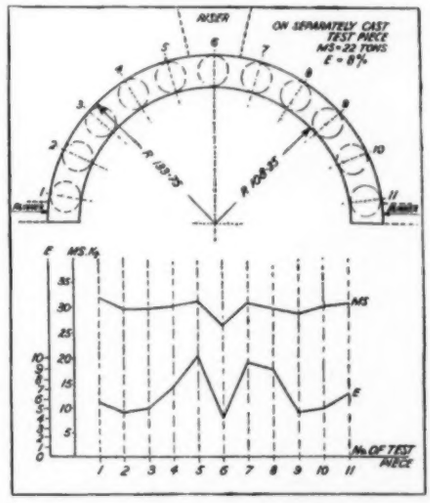


FIG. 7. SCHREIBER AND MENKING TEST, WITH RESULTS FOR A.P.33.

Investigation of a Casting in A.P.33

Structural homogeneity—Influence of feeding.—As indicated above, the mechanical properties recorded were obtained on sand-cast test-pieces; this procedure served as a method of estimating the intrinsic quality of the metal. A.P.33, like all alloys with a long freezing range, does not exhibit entirely uniform properties at all points

in a casting possessing thick and thin sections. To investigate this characteristic two methods were employed: (1) Cutting of test-pieces from castings previously heat-treated; and (2) casting of special test-pieces as suggested by Schreiber and Menking.

Test-pieces cut from castings showed that in the thin sections the mechanical properties are equal or even superior to those obtained on specially cast test-bars. In thick sections, and in those from unfavourable sites (by locating the body of the test-piece on a large runner, for example), tensile figures attained values of 70 to 75 per cent. of those normally obtained, and elongation figures reached 50 to 60 per cent. of the normal value.

The test indicated by Schreiber and Menking* consists in making a casting of the form illustrated in Fig. 7. The casting is provided with two runners at opposite sides of the hemicylinder and is fed by a large riser located at the crown of the arch. After heat-treatment the casting is divided into an odd number of segments which furnish an equal number of tensile test-pieces. For eleven specimens, for example, Nos. 1 and 11 would be taken directly against the runners whilst No. 6 would be cut exactly below the riser. Fig. 7 illustrates graphically the results obtained on each specimen.

For a melt of A.P.33 giving on a separately-cast test-piece M.S. = 22 tons per sq. in. and E = 8 per cent., the following results were obtained:—

Test-pieces 1 and 11, M.S. = 19.6 to 20.3 tons; E = 5.5 to 6.5 per cent.

Test-piece 6, M.S. = 16.8 tons; E = 4.0 per cent.

Test-pieces 5 and 7, M.S. = 19.7 tons; E = 9 to 10 per cent.

Other test-pieces, M.S. = 18.4 to 19 tons; E = 5 to 8 per cent.

It is clear that in castings of A.P.33 which are prepared under correct conditions, quite a satisfactory margin of safety is assured.

Review of Certain Alloys derived from A.P.33

Numerous investigations have been carried out to improve the properties of A.P.33 by the addition of other elements. In general, excepting for A.P.33 with additions of magnesium, the results obtained possess no special interest, although the marked influence of traces of tin on the tensile properties should be noted.

A.P.33 with Addition of Tin

An addition of approximately 0.02 per cent. of tin effects slight improvements in the ultimate strength and elongation of the quenched and tempered alloy. Additions of 0.08 to 0.12 per cent. of tin yield, on the quenched and tempered alloy, a tensile strength of 26 to 27.3 tons per sq. in. and a Brinell hardness of 140 to 145, but the elongation drops to approximately 1.0 per cent.

A.P.M. Alloy

The alloy known as A.P.M. is identical in composition with A.P.33 excepting for the addition of approximately 0.20 per cent. of magnesium. This addition confers certain characteristics on the alloy which render it not only of especial interest but also superior to normal A.P.33.

Mechanical Properties of A.P.M.—Tests were carried out on 18 mm. diameter test bars cast in green sand and machined to 13.8 mm. diameter.

Results after Heat-Treatment

Elastic Limit (0.02 per cent. proof stress); 11.4 to 13.3 tons per sq. in.

Elastic Limit (0.2 per cent. proof stress): 13.9 to 16.5 tons per sq. in.

Ultimate Strength: 21.5 to 25.4 tons per sq. in.

Elongation: 22 to 28 per cent.

Brinell Hardness: 95 to 115.

* "Z. f. Metallkunde," 1920, p. 298.

Impact (Mesnager test piece): 1 to 1.5 kg. m. per sq. cm.

The mechanical characteristics of A.P.M. are thus appreciably superior to those of A.P.33, the elastic limit being decidedly raised, and the tensile strength, elongation and Brinell hardness being somewhat increased.

Heat-Treatment.—A.P.M. is treated in exactly the same way, both as regards temperatures and duration of heating, as A.P.33. Owing to the presence of magnesium, however, the alloy tends to age-harden after quenching, and after 4 days' ageing at room temperature, the mechanical properties of the alloy are equivalent to those obtained by annealing at 140 deg. C. for 8 hours. This fact permits the suppression of the annealing operation—a fact of value in industrial practice.

It should be noted that this advantage is slightly qualified. It often happens that some castings undergo a little deformation after quenching; those in A.P.33 are easily restored. Castings in A.P.M. are only slightly more rigid

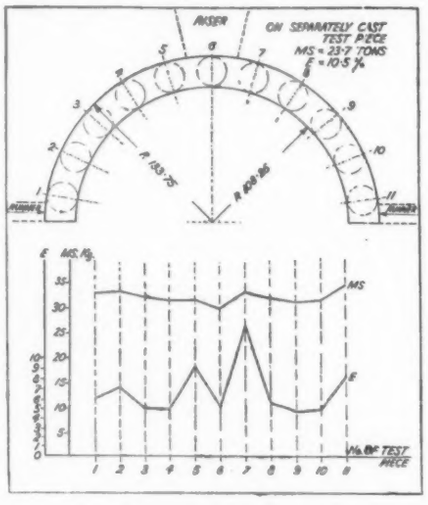


FIG. 8.—SCHREIBER AND MENKING TEST, WITH RESULTS FOR A.P.M.

immediately after quenching, but owing to rapid ageing they quickly become very rigid. A lapse of 12 hours makes the operation very much more difficult, and the straightening operation should be carried out during the first few hours after quenching.

Melting and Casting Technique

The precautions cited for A.P.33 apply equally to A.P.M., excepting that the latter does not tend so readily to become coarsely crystalline with repeated remelting. However, the action of the regenerating flux is much less efficacious in the case of A.P.M. than in that of A.P.33.

It is necessary to take into account the slow but continuous impoverishment in magnesium which occurs during the course of successive remelting.

Properties of A.P.M. Castings

Tests carried out in accordance with the suggestion of Schreiber and Menking on a quenched and aged casting in A.P.M. gave the results illustrated in Fig. 8.

The commercial production of A.P.M. has actually commenced and it is being produced in large-capacity furnaces as readily as A.P.33.

DR. J. DONALD POLLOCK has been elected President of the British Oxygen Company, Limited, and Mr. S. J. L. Hardie chairman of the board of directors. Sir Alexander Stewart, chairman of the Commonwealth Industrial Gases, Limited, of Australia, has been elected to a seat on the board. Dr. Pollock had previously been chairman of the company and Mr. Hardie vice-chairman.

The Institute of Metals

The twenty-ninth annual autumn meeting of the Institute of Metals was held in Sheffield from last Monday until to-day, by invitation of the local section of the Institute and with the co-operation of the industrialists and the University of Sheffield. The meeting began last Monday evening, with a reception in the Mappin Hall, of members and their ladies by the Lord Mayor of Sheffield (Councillor Mrs. A. K. Longden, J.P.), the Senior Pro-Chancellor (Lieut.-Colonel Sir H. K. Stephenson, Bart., D.S.O., D.L., LL.D., J.P.) of the University of Sheffield, and the President (Mr. W. R. Barclay, O.B.E.). After speeches of welcome by the Lord Mayor and the Pro-Chancellor, and a reply by the President, a short business meeting took place, at which there were announced the following names of Officers nominated for 1938-39:—*President*: C. H. Desch, D.Sc., Ph.D., F.R.S. *Vice-President*: Prof. J. H. Andrew, D.Sc. *Members of Council*: J. W. Donaldson, D.Sc.; Engineer Vice-Admiral G. Preece, C.B., and H. S. Tasker, B.A.

The Sixteenth Autumn Lecture on "Metallurgy and the Aero Engine" was then delivered by Dr. D. R. Pye, C.B., M.A., F.R.S. (Director of Scientific Research, Air Ministry), and this is printed elsewhere in this issue.

The general meeting was resumed on Tuesday morning, when a number of Papers were presented for discussion. At the conclusion of the morning session the members were entertained to luncheon at the Royal Victoria Station Hotel, and in the afternoon visited the following works:—United Steel Companies, Limited (Templeborough Works); English Steel Corporation, Limited; Brown Bayley's Steel Works, Limited; and Mellowes & Company, Limited. In the evening, at the Town Hall, there was a civic reception and dance given by the Lord Mayor of Sheffield.

Yesterday there was held the concluding session for the presentation and discussion of Papers. After luncheon—at which members and their ladies were entertained by the Local Committee at the Royal Victoria Station Hotel—members visited the following works:—Thos. Firth & John Brown, Limited; Edgar Allen & Company, Limited; Hadfields, Limited (East Hecla Works), and Walker & Hall, Limited. In the evening members and their ladies were entertained at a banquet and dance at the Royal Victoria Station Hotel.

To-day is being devoted to a whole-day motor excursion, members and their ladies being conveyed through some of the beauty spots of Derbyshire. Luncheon will be served at the Palace Hotel, Buxton, and on the way home members are to be entertained to tea by Prof. and Mrs. Andrew.

Catalogues Received

Fans. Davidson & Company, Limited, Sirocco Works, Belfast, have used a rather striking folder to bring many phases of fan products to the notice of recipients, especially those involving the movement of air or hot gases.

Aluminium. The British Aluminium Company, Limited, of Adelaide House, King William Street, London, E.C.4, have repaired a breach in their publicity front, by issuing a 12-page booklet which very briefly and in an interesting manner covers the whole of their productions. We know of no other of their catalogues or pamphlets which quite fulfils this purpose. Ample recourse has been made to illustration, and the only serious omission, to our mind is that this, of all their publications, should not carry a short list of their more technical brochures.

Metallurgy and the Aero Engine*

By D. R. PYE, C.B., M.A., Sc.D., F.R.S.

If one compares two aero-engines of roughly the same type and cylinder capacity, the one a 1937 model and the other of about six years earlier, the outstanding fact is that in six years the maximum power output, expressed as h.p. per cub. ft. of cylinder capacity, has increased by amounts which vary in different designs between 50 and 100 per cent. In outward appearance the engines are very similar. How, then, does one achieve an output nearly twice that of its predecessor of six years ago? Many people would reply that this satisfactory result is almost entirely due to the improved quality of the fuel supplied to it, because this allows the combustible mixture to be supplied at a much higher temperature and pressure, and at the same time to be more highly compressed in the cylinders, without the combustion taking on the characteristics of a detonation which is destructive in its effects. It is true that without this improved fuel only a small part of the 100 per cent. increase of power could have been achieved; but it is of interest to inquire in what respects the engine itself has had to be developed, with the improvement in the fuel and the greater quantity of combustible mixture supplied to each cylinder per stroke, to enable it to withstand this forcible feeding. For the most part it is the metallurgist who has made this possible.

It must be understood that if the present-day fuel had been available five years ago the power of the engines could not have been safely increased by more than a comparatively small amount. It is impossible to say where the engines would have failed, but fail they would, either in bearings, cylinder bolts, valves, pistons, or sparking plugs.

Of the two pairs of engines shown in Figs. 1 and 2, each outwardly so similar, there is hardly one major component of which either the material or its treatment has not been modified and improved in the last five years to meet the far more severe conditions of to-day.

The problems introduced by an increase of power one may classify broadly as thermal and mechanical. On the thermal side the problem can be stated in general terms by saying that an internal-combustion engine draws into its cylinder per minute a certain weight of combustible mixture which depends upon the product of the engine speed and the density of the air supplied. Combustion of the mixture then generates an amount of heat per minute in direct proportion to its weight, and of this total heat generated a certain fraction—which is called the engine's thermal efficiency—is converted into mechanical work at the crankshaft.

The possibility of increasing this fraction of the total heat generated which an engine converts into mechanical work is strictly limited. It is fundamentally impossible to increase it very greatly, and between the engines of to-day and those of six or seven years ago the increase has in fact not been more than about 10 per cent. The important conclusion from this fact is that an increase of power of 100 per cent. is inevitably accompanied by an increase, in nearly the same ratio, of the *waste* heat, which must be dissipated with the exhaust gases and by conduction through the various metal components of the cylinder.

The greater part of this increase of waste heat goes out with the exhaust gases; but for 100 per cent. increase of total heat generated per minute there is at least a 40 per cent. increase of that communicated to the cylinder walls and other components, to be dissipated by conduction. Moreover, that conduction has to be effected without allowing rises of temperature in the various components which will prejudice their mechanical working one with another, for example, the pistons with the cylinder walls, and the valves in their guides. So far as direct conduction through the cylinder walls is concerned it is found that in order to dissipate this heat without an excessive rise of temperature in the cylinder barrel and head, the fin area on air-cooled cylinders of the same size has been increased by about 95 per cent. in the last five years. Even so there has probably been some increase in the average temperature of the inner surface of the cylinder barrel which may now be as high as 180 deg. C.

The material employed for cylinder heads of air-cooled engines has not changed much in recent years, and development has been rather towards improving the forging and machining qualities. The light alloys have good conductivity compared with steel in any case, and as compared with the thermal problems inherent in pistons, valves, valve seats, and sparking plugs, those of the cylinder head itself are less acute. As regards steel for the cylinder barrel, the essential requirements are good machining qualities combined with the possibility of special treatment of the working surface. The question of surface condition as affecting friction and lubrication will be returned to later. Although operating temperatures are vitally important, the subject falls more appropriately into the class of mechanical problems, to be dealt with later.

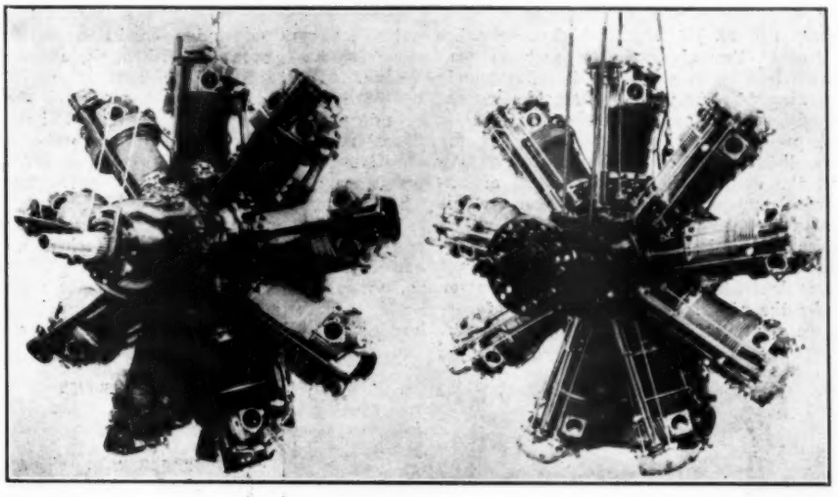


FIG. 1.—(LEFT) BRISTOL PEGASUS XXII (1936); POWER FOR "TAKE-OFF" 1,010 H.P. (RIGHT) JUPITER VII F (1929); POWER FOR "TAKE-OFF" 460 H.P.

Pistons and Crankshafts

Of the many components in which a weakness may cause breakdown of an engine there are two which remain, perhaps, the major preoccupation of the designer: the piston and the crankshaft and its bearings. The problems of the piston are chiefly thermal, and those of the crankshaft, mechanical. The piston is the most sensitive and vital part of the engine, and at the same time the least possible to observe in operation, or to repair. It cannot avoid receiving as much as 40 per cent. more heat per minute over its top surface, and all the heat it receives must be dissipated either to the cylinder walls across an oil film, or from the under-side to the air and oil in the crankcase. Cooling from the under-side of the piston is comparatively small, and the only methods of avoiding a big rise of temperature in the material is to have a higher thermal conductivity in the material, or to increase the thickness of the piston crown, so that the heat is rapidly transferred to the periphery without large differences of temperature along the radius. The change from a cast-iron to an aluminium alloy piston, under the same full throttle conditions, caused a fall of the maximum temperature in a 4-in. dia. piston from about 450 to 250 deg. C., owing to the better heat conductivity and the greater thickness allowable of the light metal. It is typical, however, that these figures can only be given as rough approximations, because of the virtual impossibility of direct observation under real working conditions. Temperature observations by thermocouples have been successfully made up to about 1,500 r.p.m. with the aid of elaborate gear on a single cylinder engine, but the difficulty of leading out the electrical connections to stationary measuring points outside the engine is extreme, and to do so would be impossible on a complete aero-engine. Even on a single cylinder engine the number of connections limits the number of thermocouples to about six. From examination of the re-crystallisation of aluminium alloy pistons after use, it is presumed that the temperature at the centre of the crown, even with this material, may nowadays reach temperatures in the neighbourhood of 450 deg. C. What it really is, is perhaps not very important, because whatever the bare truth may be the aero-engine designer will always force piston temperatures as high as the design and the material permit. In the last five years the ability of piston materials to maintain the necessary strength at high temperatures has undoubtedly improved, although reliable figures would be difficult to postulate. Nevertheless, for the sake of the necessary strength, and also to allow of an adequate rate of heat-flow to the periphery, it has been necessary to thicken the piston crown and use a heavier piston. Any new material of specific gravity not greater than 3.0—but the lower the better—and of thermal conductivity not inferior to "Y" alloy, which at the same time is able to maintain its mechanical properties better than "Y" alloy at temperatures of 300 deg. C. and over, will be of major importance to the aero-engine of the future.

The Exhaust Valve

The 100 per cent. increase in the waste heat from the cylinder has profoundly affected the design and metallurgy of the exhaust valve in the last five years. It would surely be difficult to find anywhere so many thermal, chemical, and

* From the Sixteenth Autumn Lecture presented to the autumn meeting of the Institute of Metals held at Sheffield from last Monday until to-day. The author is director of Scientific Research at the Air Ministry.

metallurgical problems concentrated in so small a space. The difficulty of direct observation is not so great with the valve as with the piston, but the problem is far more complex. The successful development of the poppet valve and the seat on to which it closes calls for the most expert observation, and a critical analysis of the facts based upon wide knowledge of materials and engine design. For example, suppose an attempted run of 100 hrs. at high output has been stopped through a failure such as that illustrated in Fig. 3, which one describes loosely as " burning " of the valve. There is a variety of possible causes, such as overheating; but it is more probable that local overheating is due to some distortion of the valve or its seating ring in the cylinder head, on account of unsymmetrical expansion with temperature. This prevents perfect closure of the valve and allows an escape of burning gas under the full cylinder pressure. Or, again, the imperfect closure may have been of a more accidental character caused by the pinching of a little piece of carbon or scale between the valve and its seat; and besides these mechanical and thermal possibilities, there is the chemical aspect introduced by the presence of tetraethyl lead in the fuel.

All the fuels demanded to-day by engines of the highest output owe their quality in some degree to the presence of the well-known " ethyl fluid." This is a mixture of tetraethyl lead with ethylene dibromide and other substances, and it introduces a whole series of problems for the exhaust valve. It decomposes during the combustion in the cylinder with the formation of lead oxide and lead bromide, and the former of these, at the temperature of the exhaust gas, has disastrous effects upon the steel of the valves. The effects of the lead compounds on the exhaust valve are very much dependent on the valve temperature, and hence on engine output, and only become very serious when the valve is working under conditions far more severe than are ever met with in the automobile engine. Engine conditions, indeed, are extraordinarily critical. It has been found that a cylinder which will easily survive a hundred hours' running, when developing a brake mean effective pressure of 180 lbs. per sq. in., will consistently fail through exhaust valve trouble when the power is increased by 10 per cent.

The most popular valve steel in use to-day is one containing 12 to 14 per cent. each of nickel and chromium, but in spite of a high innate resistance to corrosion attack, it is not able, by itself, to withstand oxidation in the presence of lead oxide at high temperatures. To overcome this, advance has been along two lines: first, a complete re-design of the valve to maintain better cooling; and, secondly, the covering of the seating ring, and now even the whole head of the valve, by stellite, a very hard alloy composed of cobalt, chromium and tungsten, with about 2½ per cent. of carbon, which has a better resistance to the effect of the lead.

The problem of cooling the valve is, like that in the piston, one of transferring the heat from the point where it is received—the head—to some point where it can be dispersed; ultimately, of course, to the surrounding air, but immediately to the metal of the cylinder body. With the mushroom valve there is little hope of getting rid of the heat directly from the head, and the problem is that of transporting it to the cooler stem, and thence across the working surface between the stem and the valve guide.

Twenty years ago, experiments were made at the Royal Aircraft Establishment on the removal of heat from the head to the stem by making the valve hollow and filling it with a fluid which was shaken up and down by the valve's motion. At first, mercury was tried, and later a eutectic mixture of potassium and lithium nitrates. The suggestion was at that time premature, because the steelmakers were able to produce better non-scaling steels which could work for long periods at a red heat, prior to the introduction of tetraethyl lead. In the last five years the introduction of the chemical problem has forced designers to obtain better cooling, and to face the complication and expense of the hollow valve, containing metallic sodium as its heat carrier, which is now becoming universal in high-duty engines. In Fig. 4 are shown cross-sections of three slightly varying types of " liquid-cooled " exhaust valve. The sodium is solid when cold, but melts at about the temperature of boiling water.

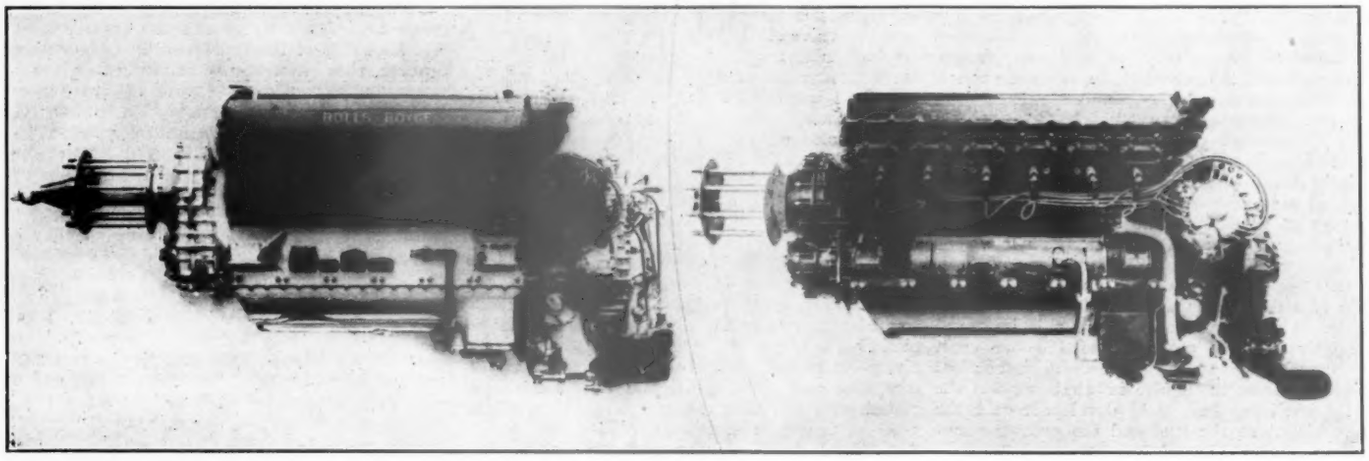


FIG. 2.—(LEFT) ROLLS ROYCE KESTREL XVI (1937); POWER FOR TAKE-OFF 870 H.P. (RIGHT) KESTREL II S (1931); POWER FOR TAKE-OFF 534 H.P.

FIG. 3.—BURNT EXHAUST VALVE.

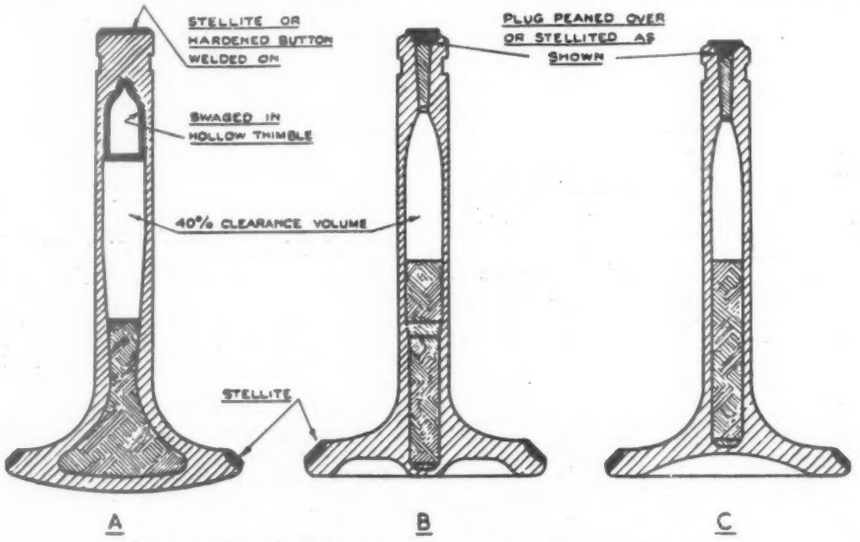


FIG. 4.—THREE TYPES OF SODIUM-COOLED EXHAUST VALVE.

Even this complex design, however, combined with the stellite surface treatment, has not sufficed to cure the troubles of the exhaust valve. There is evidence of a rapid increase in the rate of attack even on stellite, in the presence of lead oxide, between 600 and 700 deg. C. and again above about 900 deg. C. The practice of covering the whole top surface of the valve, moreover, to prevent scaling, has led to trouble owing to a difference between the coefficients of expansion of the steel and the stellite, which has been found to cause cracking of the stellite over the head surface, so that the covering has completely disintegrated after 50 or 100 hrs. of high-duty running. A new material composed of about 80 per cent. nickel and 20 per cent. chromium has recently been tried for the same purpose and appears not to suffer in the same way when spread over the valve head. A possible further development is the fabrication of the entire solid parts of the valve from this non-ferrous alloy, thus avoiding the difficult welding processes involved in the composite valve.

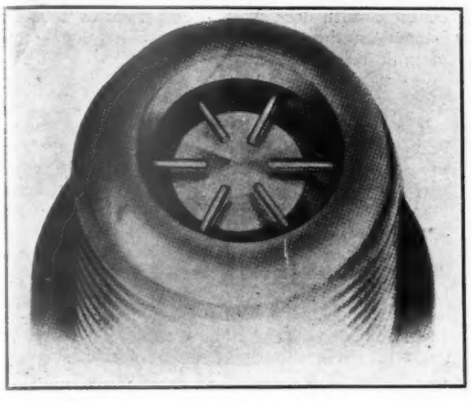


Fig. 5.—Sparking Plug with Negative Electrode of Platinum-Iridium Wire.

Finally, although the liquid sodium filling suffices to convey heat more rapidly from the valve head to the stem, it still remains to get this heat across the rubbing surface between the stem and the valve guide.

Sparking Plugs

The problems relative to the sparking plug are thermal and chemical, and although they centre mainly on the insulating material, mica or porcelain, and are therefore outside the scope of this lecture, there are also points of great metallurgical interest on which the co-operation of the pure physicist might be of value.

The magneto is called upon to produce a spark across the plug points in a gas at about 10 atmospheres pressure, while itself surrounded by air which may be at only $\frac{1}{2}$ to $\frac{1}{3}$ of normal atmospheric pressure. The necessary sparking voltage is increased by supercharging, while surface leakage and corona discharges are promoted by the low pressure outside the cylinder. It is obvious, therefore, that the magneto problem becomes increasingly severe with highly supercharged engines at great heights and that all possible means must be used of reducing the minimum voltage which the magneto has to supply across the plug points. It is found that this voltage is very much greater when it is of an "impulsive" character—that is, rapidly rising and falling again as it is in a magneto—than when a steady voltage is gradually increased until a spark passes; and, moreover, that the magnitude of the impulsive voltage depends very much on the metal of which the plug points are made. For example, the "impulse ratio," that is, the ratio of the impulsive to the steady voltage, was found to be only 1.1 with nickel as compared to 1.6 with tungsten points. It depended also upon whether the high-tension lead was positive or negative.

The sparking voltage depends on the length of the spark gap, and erosion of the plug points under the electric discharge produces in service a steady increase of the gap and of the voltage. The increase in length of the gap under comparable conditions was found to vary in the ratio of nearly 20:1 from $\frac{1}{10000}$ in. in 100 hrs. for tungsten up to $\frac{1}{50}$ in. for nickel.

The frequency of sparking plug replacement will depend upon the rate of erosion, and it is clear that the metals one should choose from the point of view of voltage impulse ratio are not the best from the point of view of erosion. In the matter of erosion the chemical problems of fuel containing tetraethyl lead must also be considered. There is definite evidence of an increase in the rate of erosion on a change over to leaded fuel. These very practical problems of impulse ratio and rate of erosion lead direct to problems in pure physics in which the relative ease of throwing off the atoms of different metals from the plug points under the electric forces, and of electrons from the atoms themselves, need to be studied.

Apart from the electrical aspect, the sparking plug has to be designed to fulfil two contradictory conditions: it has to be so hot that any lubricating oil splashed on it will be burned away, and yet so cool that there is no danger that ignition of the fuel-air mixture can occur at the hot points before the spark passes. These are, indeed, the overruling conditions, for hitherto the magneto, although hard pressed, has been equal to the electrical problem. An interesting new development is a plug on which the negative points are formed from fine platinum or platinum-iridium wires $\frac{1}{50}$ in. in diameter placed radially and close to the flat topped positive electrode, as illustrated in Fig. 5. The fine wires eventually erode away, but being parallel to the flat top of the central electrode, this does not alter the size of the gap. Furthermore, the fineness of the wire probably allows rapid cooling of the sparking points during the induction stroke of the engine, and this prevents pre-ignition. The plug clears itself when oiled up. An interesting point in connection with the erosion is that when platinum-iridium wire was used it was mainly the platinum which was removed, leaving the iridium behind; but when pure platinum wire was used the resistance to erosion was greater than that of the platinum-iridium alloy under similar conditions.

Mechanical Problems

The mechanical problem of maintaining two surfaces rubbing without seizure occurs in a variety of forms in the internal combustion engine. There is the crankshaft in its bearings, in the first place, and the piston in the cylinder; but equally important and interesting to the metallurgist is the problem of wear between the valve stems and their guides, and of the camshaft and other parts of the valve gear. In each one of these directions the last five years have brought changes in the material and the technique used in the preparation of the working surfaces, always in the direction of providing greater hardness to resist wear and "pick-up" under heavy loads. For the cylinder surfaces in both liquid- and air-cooled engines a change either to special steels capable of extreme hardening or to chromium-plated surfaces is being made. Similarly, the so-called lead-bronze has almost entirely replaced white metal as the bearing material, and this in its turn has involved the use of a hardened steel shaft to prevent excessive wear.

The problem of wear, seizure, and "pick-up" between metal surfaces obviously cannot be considered apart from the question of lubrication, which under ideal conditions may preclude metallic contact entirely. Indeed it may be said that every surface, unless it has been chemically cleaned with the greatest care, is lubricated in some degree.

Molecules and Molecular Dimensions

Any surface, solid or liquid, is composed of molecules in motion, and a perfectly smooth surface would be one in which any irregularities were of molecular dimensions. One can picture the free surface of an undisturbed liquid as being smooth in that sense. It was the view of the late Lord Rayleigh that the difference between a liquid and a finely polished solid surface was not great, and that elevations on the solid surface would be of molecular dimensions. At the same time it must be remembered that the finest available test for the flatness, as distinct from smoothness, of a surface would only detect "hills" and "valleys" equal to a height of about a thousand molecules. Fig. 6 is intended to give some idea of what two supposedly flat surfaces, pressed together with an oil film between, would look like if sufficiently magnified. They touch only at the two points A and B.

When two surfaces slide past one another they may, in effect, be floating past one another on an almost continuous film of oil. This would be the state of things in a well-lubricated crankshaft bearing. On the other hand, the conditions may not be favourable to the maintenance of a continuous oil film. This is true between the piston and the cylinder, and more especially between the piston rings and the cylinder. In these circumstances the metal surfaces, as they slide past one another, come into contact, but only intermittently, and at points which are

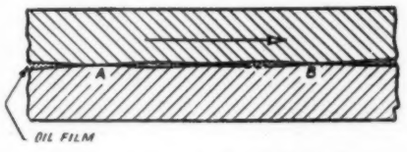


Fig. 6.—Conception of Two Supposedly Flat Surfaces pressed together with Oil Film between. There is contact only at A and B.

constantly changing. Remembering Fig. 6, it can be said that there is contact at the "hill-tops" when these come opposite to one another, but that between-whiles the surfaces are separated by an oil film thick enough to contain many thousands of oil molecules. Thirdly, the surfaces may carry no visible lubricant at all, as may happen between a valve stem and its guide; or the load may be so concentrated, as on the working surface of a cam, that any thick film of oil is instantly squeezed away.

An interesting case of invisible lubrication between a steel valve and its bronze guide was experienced on a well-known radial air-cooled engine. No special lubrication was provided for the valve-stem, but it was quite able to run for some hundreds of hours without appreciable wear of the guide. Then some experiments were made, running the engine on a very economical fuel-air mixture so that there was insufficient fuel to use up all the oxygen of the air, and it was found that the engine could not be run for more than 20 hrs. on account of excessive wear of the valve guides. The explanation appears to have been that under normal conditions a minute quantity of oil, or perhaps only oil vapour, was finding its way down by the valve stem and providing an invisible lubricating film. When, however, there was any free oxygen left by the fuel, the oil vapour was burnt up and the wear increased by many hundreds per cent.

Friction, Wear and Lubricating Oils

It used to be thought that the force of friction which opposes the sliding of one surface over another was always due to a sort of interlocking of minute asperities at the points of contact, however perfectly the surfaces might be polished. That view is obsolete, and it is now thought that the resistance to motion is due to cohesive forces between the molecules themselves acting across the interface between the surfaces, and that these forces are of the same kind as the cohesive force between the molecules of a solid

on which its strength depends. These cohesive forces between the molecules are very powerful at short range, but the range is extremely small. Remembering the "undulating" character of any smooth surface when considered in terms of molecular dimensions, it is clear that it is only over a small fraction of the apparent area of contact of two surfaces that the molecules will be brought within each other's range of attraction and that, owing to the short range of action of the cohesive forces, even a single and quite invisible layer of oil molecules between two surfaces will suffice to prevent the molecules in each from getting to grips with one another.

Whenever and wherever they do so, however, they will cohere with a force equal to that of the metal itself, and some molecules of one surface will be torn away, held firm by the molecules of the other; in other words, either wear or "picking-up" will occur.

It is of interest that even in a well-lubricated shaft bearing, minute adhesions have been observed to take place between the shaft and the bearing metals without these adhesions having proceeded to the point of a seizure. The experimental evidence is that a sliding of one surface on another will always cause some slight abrasion, due to this metallic cohesion, unless the surfaces are protected by a layer of oil molecules. Even when they are so protected, temperatures are produced in the surface layers, wherever there is contact, which are so high as to decompose the oil, and one has to imagine an extremely rapid succession of break-downs and repairs of the oil film. It may be that the force of friction, once complete fluid lubrication has ceased, is due to the cohesion and parting again of innumerable pairs or groups of molecules, and that the observed value of the force is really an average result derived from a rapidly alternating state. If this be so, the likelihood of wear or of seizure must depend ultimately on the magnitude of the cohesive forces between the molecules on the two surfaces. Now the nature of these molecular forces which may be fatal to a bearing is essentially the same as the forces of chemical affinity, and just as the elements show a wide diversity in their eagerness to form chemical compounds with one another, so bearing surfaces must differ in their readiness to cohere when lubrication has failed. There are, of course, plenty of instances of two metals, A and B, which will work harmoniously together when A and C, under exactly the same conditions of load and temperature, will produce a seizure. Ability to preserve metal surfaces rubbing without seizure, in spite of heavier loading and rising temperatures, is vital to progress with the high-duty internal combustion engine.

Nature and Behaviour of Surfaces

So long as a complete, unbroken oil film is maintained, this question of the proper "pairing" of metals does not arise, but even in a well-lubricated bearing there are the "humps" and "hollows" already described, and whenever two humps pass one another so that they are helping to carry the load on the bearing, then the oil is squeezed away until there is no more than a single layer or so of oil molecules between the surfaces; very high temperatures are produced, and intermittent failure of the oil film and metallic cohesions will occur. So long as this state persists, the two surfaces are said to be in the state of "boundary lubrication."

It is easy to understand why high temperatures of the metal surfaces make the danger of seizure more acute. In the first place, the rate at which the oil is squeezed from between the surface humps as they approach will depend on its viscosity. As temperatures rise, the viscosity falls, the thick film of oil is more quickly dispersed and the dangerous condition of boundary lubrication is earlier established. Besides this, however, there is the effect of a higher temperature on the danger of metallic cohesion when the oil film breaks down. At a higher temperature all chemical activity is enhanced and there is, therefore, *prima facie*, likely to be a direct effect of temperature in the direction of promoting metallic cohesion and seizure.

Accepting that between two heavily loaded surfaces in contact a condition of boundary lubrication, though intermittent, is constantly recurring and that however good the oil, opportunities for metallic cohesion will occur, it is of great interest to consider what it may be possible to do to the metallic surfaces themselves to obtain relief and reduce the danger of seizure.

Reference has already been made to the parallel between the forces of metallic cohesion and of chemical affinity and of the engineer's experience that some metals show less readiness to seize together than others. It is now proposed to deal with the light thrown by recent research work on the ultimate nature of surfaces, and how they may differ, and from that to suggest how the special treatment of surfaces may perhaps assist in the engineer's problem. The normal condition of a smooth metallic surface may be described as a crystalline aggregate with the atoms or molecules within each crystal arranged in a regular manner according to a "space-lattice" which is characteristic of the metal. On the surfaces of most liquids, on the other hand, the molecules, if one could see them, would appear completely without order of any kind, and there are many solids also which have this amorphous atomic structure.

Beilby, a Past-President of the Institute of Metals, after a careful microscopic study 35 years ago of the process of polishing, suggested that this did not consist simply of a rubbing away of asperities to smaller and smaller dimensions, but that the act of polishing produced a fundamental change in the character of the surface either of a metal or non-metallic crystal, during which the crystalline character is lost and the molecules become arranged "all higgledy-piggledy" in the way characteristic of a liquid surface. The correctness of Beilby's conclusion and the frequent occurrence of this amorphous layer, now known as the "Beilby layer," on a polished metal, is generally accepted. It has received remarkable confirmation from the work of Bowden, and more recently from that of Finch and others with the electron camera. Bowden showed that when two metals were rubbed together, even quite lightly, temperatures could be recorded electrically at the surface which quickly rose to the melting point of one of the metals, and that by no increase of load and rubbing speed could the temperature be made to rise higher. He has since extended his observations more particularly to polishing, and finds evidence that the surface temperature, when a surface is rubbed with a polisher, always rises to the melting point of the polished surface. It must be understood, of course, that the very high temperatures are confined to an excessively thin layer on the surface, and do not spread perceptibly throughout the body of the metal.

An obvious deduction from these observations is that during the act of polishing, a liquid or semi-liquid layer of the metal is smeared over the underlying crystalline surface and, hardening again immediately, retains the amorphous character it had as a liquid.

Finch has confirmed this conclusion, but has further reached the extremely interesting and important one that this amorphous layer left by polishing may or may not remain amorphous according to the material polished and how it has been treated. The thickness of the amorphous layer varies widely according to the material and the amount of polishing, from a layer only 20 to 30 atoms thick up to one of 100,000 or more. By examination of some new and some used aero-engine cylinders, Finch found that the "running-in" process between the piston and cylinder results in an extremely thick Beilby layer being formed: so thick, that several rubbings with fine emery paper were necessary to remove the hard amorphous layer and re-expose the crystalline substratum.

It is, of course, common knowledge to the engineer that he must not allow an engine to give its full power until the "running-in" process is complete, or scoring and seizure between the piston and cylinder will infallibly occur. This conforms with the physicists' observations upon the Beilby layer, that metal in its amorphous condition is in general harder and tougher than the crystalline variety. Moreover, what is probably more important, so long as the surface is crystalline one must expect its ultimate nature to be, as it were, a forest of minute crystalline peaks, rather than of the nature of a liquid at rest on which the surface irregularities are of molecular dimensions. It is fairly obvious that a metal surface of this latter type will be much more easily protected by an exceedingly thin oil film than a surface on which there are crystalline peaks each hundreds of thousands of atoms high, which will pierce the oil film and make metallic contact, with local high temperatures and an immediate danger, or even certainty, of some metallic cohesion.

Polished Surfaces

The forces exerted by the atoms in the underlying crystal always try to rearrange the atoms in the amorphous Beilby layer, and in some materials they succeed, so that the polished layer is found to show some crystalline character under the electron beam. On other materials the amorphous layer shows a great reluctance to recrystallise. The forces of order exerted from the underlying crystal fail to bring about any rearrangement, the diamond being in a class by itself. Prof. Finch was never able to detect the slightest trace of surface flow as a result of polishing. The polish on a diamond appears to be simply a rubbing down of the crystalline excrescences to smaller and smaller dimensions without their ever losing their typically crystalline character. Diamonds seem a long way from the internal-combustion engine, but it is quite possible these phenomena may prove of great importance, if they lead to means for controlling the condition of the surface layer of metals used as bearing surfaces.

One of the substances which exhibited a stable amorphous layer after polishing was spinel, which is a magnesium aluminate with aluminium oxide in solid solution. Finch has suggested that if a suitably oxidised magnesium-aluminium alloy surface is used, it is possible by polishing this "to form spinel with a permanently amorphous and therefore smooth Beilby layer." The usual aluminium alloys used for pistons, on the other hand, become spontaneously covered with a thin layer of very hard aluminium oxide. This oxide layer is, or can be made, amorphous, but Finch's observations gave evidence that during the process of running-in, the oxide layer, instead of settling down into a smooth amorphous bearing surface, became converted into a layer of minute sapphire crystals. It has long been known that the wear of the cylinder barrel is more severe with an aluminium than with a cast-iron piston in spite of the greater softness of the former. It has hitherto been supposed this was due to the embedding of abrasive particles in the soft aluminium piston, but the explanation of Finch that aluminium forms its own peculiar kind of grinding surface with sapphire teeth, is not only more picturesque, but probably more true also.

Cast Iron as a Bearing Metal

Cast iron is an example of a material long known to be in the first rank as a bearing material, and here recent research has shown conclusively that it owes its quality to a unique faculty for preparing its own bearing surface.

(*Concluded on page* 204.)

Desulphurisation of Pig-Iron and Steel

By T. P. COLCLOUGH, D.Sc., M.Met., F.I.C.*

In the manufacture of iron and steel, one of the most important factors has been the control of the sulphur content of the product. The difficulties presented by the elimination of this element have imposed serious limitations on both the processes employed and the character of the raw materials which could be used as the basis of manufacture. To overcome these difficulties, attention has been focussed on methods for the removal of sulphur as a separate and distinct stage in the manufacturing process. This principle has been applied with marked success in foundries to the manufacture of iron castings. As is now well known, the liquid iron from the cupola is treated with sodium carbonate as it runs into the ladle. Long experience has shown that this treatment not only decreases the sulphur content of the iron, but also improves the quality of the metal, and has been of considerable benefit to the industry by giving a wider choice of raw materials.

A much wider application of this principle was described in an article in THE IRON AND COAL TRADES REVIEW for May 1, 1936, in which there was given in outline a new principle for the manufacture of pig-iron. The theoretical considerations on which this new principle was based formed the subject of a Paper to the Iron and Steel Institute in September, 1936. In brief, the object of this new principle is to produce pig-iron at the lowest possible cost by establishing in the blast furnace those conditions which will give the maximum rate of production and the lowest coke consumption per ton of pig-iron made. This can only be secured by ensuring smooth operating conditions, an easily-melted fluid slag, and open conditions in the tuyere zone, so as to promote the rapid and free combustion of the coke.

TABLE II.—*Typical Slags formed in Ladle.*

	(1)	(2)
	Per cent.	Per cent.
SiO_2	36.30	40.00
MnO	13.95	7.17
FeO	3.09	3.22
Al_2O_3	4.28	4.37
TiO_2	4.36	4.42
CaO	1.60	1.78
MgO	0.58	0.60
Na_2S	9.68	11.04
Na_2O	19.87	16.43
Na_2CO_3..	5.72	10.80
P	0.08	trace

It has been demonstrated in the Paper referred to above that to attain these results the burden of the blast furnace and the additions of flux shall be regulated in such a manner as to form a slag of the lowest possible melting point and viscosity, and this object is most nearly attained when the ratio of lime to silica in the slag is approximately unity. It has been proved in practice that under these conditions the rate of production of iron is increased, the coke consumption is decreased, and the difficulties experienced in the smelting of ores which are relatively high in alumina have been practically overcome. It has been pointed out that in this method of operation the sulphur content of the pig-iron tapped from the blast furnace is completely disregarded, and any excess of sulphur over specification or in excess of that desired for steel-making purposes is removed by subsequent treatment.

* H. A. Brassert & Company, Limited.

Desulphurisation by Sodium Carbonate

For many years it has been the practice at blast-furnace plants and in iron and steel foundries to overcome the difficulties due to high-sulphur iron by the treatment of the liquid metal with sodium carbonate in the ladle. When considering the practical application of the new method of burdening the blast furnace, it was immediately apparent that the iron would require treatment by a similar use of an alkaline reagent.

TABLE I.—*Desulphurisation of Pig-iron by Sodium Carbonate.*

Before treatment.			After treatment.			
Si.	S.	Mn.	Si.	S.	Mn.	% reduction of sulphur.
0.50	0.466	0.42	0.42	0.156	0.42	66.5
0.78	0.386	0.57	0.54	0.127	0.49	67.1
0.82	0.307	0.99	0.59	0.079	0.91	74.3
0.78	0.289	1.04	0.49	0.055	0.92	81.0
0.83	0.257	1.23	0 53	0.057	1.10	77.8

The reactions which occur with sodium carbonate are somewhat complex in character, but may be briefly indicated as follow: The sulphur in the pig-iron is generally accepted as being present in the forms of sulphides of iron and manganese (FeS and MnS). The sodium carbonate reacts with these sulphides liberating carbon dioxide and forming sodium sulphide and ferrous and manganous oxides in accordance with Equation (1).

(1) $Na_2CO_3 + FeS\ (MnS) = Na_2S + CO_2 + FeO\ (MnO)$

Under the high-temperature conditions prevailing in the ladle, part of the carbon dioxide is dissociated, liberating oxygen which may combine with iron to also form ferrous oxide in accordance with Equation (2).

(2) $CO_2 + Fe = FeO + CO$

The carbon-monoxide gas formed escapes from the metal and burns as it comes into contact with the atmosphere.

Secondary reactions may occur which result in the formation of silicates of iron and manganese. These rise to the surface of the metal forming a slag layer, possibly in accordance with Equations (3), (4) and (5).

(3) $2\ FeO + Si = Fe + SiO_2$

(4) $FeO + Mn = MnO + Fe$

(5) $2(FeO,MnO) + SiO_2 = 2(FeO,MnO)\,SiO_2$

The various chemical reactions are materially stimulated by the vigorous stirring action of the liberated carbon dioxide, which has the additional advantages of degasifying the molten metal and reducing the residual non-metallic inclusions. The sodium sulphide formed, is insoluble in metallic iron and rises to the surface forming part of the slag. Immediately the sodium sulphide at the surface of the slag comes into contact with the atmosphere, part of the sulphur burns, combining with the oxygen of the air and forming sodium oxide and sulphur dioxide which escapes into the atmosphere.

As a result of the treatment of the iron with sodium carbonate, it is found that there is in every case a marked reduction in the sulphur content of the iron, and at the same time there is also, due to oxidation, a reduction in the silicon content of the iron. The effect on the manganese content is relatively small and is usually negligible. The carbon and phosphorus contents of the pig-iron are unaltered. Examples of the desulphurisation accomplished by the use of sodium carbonate are shown in Table I, and typical examples of the slag which is formed on the surface of the metal, are given in Table II.

In each of these examples, the weight of pig-iron treated was about 50 tons and the strong desulphurising action of the sodium carbonate is clearly demonstrated.

Desulphurisation Mixture

Where very large quantities of pig-iron have to be treated, and in districts which are favourably situated for the supply of limestone and fluorspar, it has been found that mixtures of these minerals with sodium carbonate may prove more suitable and more economical than plain sodium carbonate for desulphurisation. The slag which forms on the surface of the iron after treatment with sodium carbonate exerts a fluxing action on the brickwork of the ladle and on the lining of a hot-metal mixer or steel-making furnace to which the pig-iron is transferred. To avoid this action, it is necessary to remove the slag as completely as possible before so transferring the iron. The slag formed using sodium carbonate alone is very fluid and in the early stages of the development work it was found advisable to add a small amount of limestone to the slag in order to thicken the slag and thereby facilitate the complete separation of slag and metal.

As a result of a series of experimental tests, it was found that considerable advantages may be obtained by the use of other agents in con-

TABLE III.—*Comparative Tests on Desulphurisation of Pig-iron.**

Desulphuriser.		Test 1. Sodium carbonate alone.	Test 1. Mixture.	Test 2. Sodium carbonate alone.	Test 2. Mixture.	Test 3. Sodium carbonate alone.	Test 3. Mixture.
Weight of pig-iron in ladle—lbs.		98,000	108,800	116,600	104,800	113,900	114,000
Analysis of iron—		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Before treatment	Si	1.00	0.80	0.50	0.46	1.04	1.12
	S	0.158	0.160	0.322	0.300	0.452	0.462
	Mn	1.56	1.24	0.43	0.40	0.39	0.39
After treatment	Si	0.68	0.58	0.28	0.30	0.80	0.84
	S	0.050	0.040	0.200	0.144	0.188	0.200
	Mn	1.31	1.16	0.24	0.29	0.29	0.35
Sulphur in iron—lbs.		156	174	375	314	515	526
Sulphur removed—lbs.		107	130	142	163	301	298
Sulphur removed per 100 lbs. of sodium carbonate—lbs.		9.5	23.3	12.7	29.1	26.9	53.2
Proportion of sulphur removed—per cent.		69	75	38	52	58	57

* Desulphurising agents used: (*a*) Sodium carbonate alone, 1,120 lbs. per ladle. (*b*) Sodium carbonate, 560 lbs. per ladle, fluorspar, 560 lbs. per ladle, limestone, 1,500 lbs. per ladle.

junction with the sodium carbonate as a desulphurising medium. The materials added to the sodium carbonate will, under certain conditions, act as desulphurising agents in themselves, and in addition form a slag which has a lower fluxing action on the brickwork, and is of such fluidity as to be readily skimmed from the surface of the metal. The mixture which is used also increases the efficiency of the sodium carbonate, as measured in lbs. of sulphur removed per lb. of carbonate used, by providing bases to combine with the silica which is formed in the secondary reactions referred to above and thereby liberating the whole of the sodium base for combination with sulphur.

TABLE IV.—*Desulphurisation of Pig-iron.**

Weight of pig-iron.	Mixture used.	Sulphur content.		Sulphur in iron.		Elimination, Per cent.	Sulphur removed.	
		Before, Per cent.	After, Per cent.	Before, lbs.	After, lbs.		Lbs. S. 100 lbs. Soda.	Lbs. S. 100 lbs. Soda + limestone.
115, 200 lbs. ..	A	0.380	0.158	438	182	58	76.2	16.7
125, 600 lbs. ..	,,	0.326	0.150	409	188	54	65.7	14.4
82,400 lbs. ..	B	0.584	0.290	481	239	50	54.0	14.7
102,000 lbs. ..	,,	0.426	0.160	434	163	62	60.5	16.4
112,400 lbs. ..	,,	0.360	0.130	405	146	64	57.6	15.7
115,600 lbs. ..	,,	0.348	0.076	402	88	78	70.1	19.0
100,800 lbs. ..	,,	0.300	0.096	302	97	68	45.7	12.4
100,400 lbs. ..	,,	0.262	0.060	263	60	77	45.3	12.3
102,000 lbs. ..	,,	0.124	0.054	124	54	57	15.6	4.2
118,000 lbs. ..	C	0.662	0.288	781	340	56	78.7	21.4
118,800 lbs. ..	,,	0.473	0.192	562	228	59	59.6	16.2
104,400 lbs. ..	,,	0.416	0.194	434	202	53	41.4	11.3
112,400 lbs. ..	,,	0.364	0.162	445	198	55	44.1	12.0
67,200 lbs. ..	,,	0.330	0.110	222	74	67	26.4	7.2
111,600 lbs. ..	,,	0.220	0.098	245	109	55	24.3	6.6
108,800 lbs. ..	,,	0.160	0.040	174	43	75	23.4	6.4
49,000 lbs. ..	,,	0.118	0.060	58	29	49	5.2	1.4
110,800 lbs. ..	,,	0.076	0.052	84	58	32	4.8	1.3

* Desulphurising mixture—per ladle: (A) Sodium carbonate, 3 cwts., limestone 1,200 lbs., fluorspar, 3 cwts. = 1,872 lbs.; (B) sodium carbonate, 4 cwts., limestone, 1,200 lbs., fluorspar 4 cwts. = 2,096 lbs.; (C) sodium carbonate, 5 cwts., limestone, 1,500 lbs., fluorspar 5 cwts. = 2,620 lbs.

The best results have been obtained by the use of a mixture consisting of about 25 per cent. of sodium carbonate, 25 per cent. of fluorspar and 50 per cent. of limestone. It is found that although the use of limestone instead of its equivalent weight of burnt lime exerts a greater cooling effect on the pig-iron under treatment, yet limestone is to be preferred owing to the turbulence and agitation produced by the action of the CO_2 which is liberated by the decomposition of the limestone. The volume of slag, when the mixture is employed, is approximately double that of a plain sodium carbonate slag, but in the case of the large quantities of iron contained in blast-furnace ladles, the additional cooling action of the extra slag volume is of no importance.

The results of a comparative series of tests, carried out on the same casts of pig-iron, and using in one ladle sodium carbonate alone and in the other a mixture of sodium carbonate, limestone and fluorspar, are given in Table III.

These results demonstrate the satisfactory desulphurising action which can be obtained by the use of either sodium carbonate alone or the mixture. In Test No. 1 the weight of desulphurising agent added was in excess of the amount theoretically required to remove the sulphur and it will be noted that the sulphur content of the treated iron is, in both cases, within the usual specification for basic pig-iron, and that from 69 to 75 per cent. of the total sulphur present in the raw pig-iron is eliminated by a single treatment with the desulphurising agent.

In Tests No. 2 and No. 3 where the sulphur content of the pig-iron is approximately twice and treble that of Test No. 1, the proportion of desulphurising agent used is lower than in Test No. 1. In all cases there is a marked reduction in the sulphur content of the iron and it is to be observed that the effective use of the desulphurising agent increases as the total amount of sulphur present in the iron, rises. The improvement of the desulphurising action of the sodium carbonate by the addition of fluor spar and limestone is clearly demonstrated in all three examples.

A considerable body of experience, both in Britain and abroad has now been gained on the application of this practice of operating the blast furnace with slags of low-melting point followed by desulphurising of the iron. In all cases, the operation of the furnace has been improved and the pig-iron transferred to the steel-making furnaces has been reduced to the desired standard of sulphur content.

TABLE V.—*Slag from Surface of Metal in Blast-furnace Ladle.*

	Per cent.	Per cent.
Metallic iron	1.44	0.8
SiO_2	33.15	25.25
TiO_2	2.50	2.50
FeO	7.31	6.86
CaO	16.63	22.98
CaF_2	4.06	5.65
CaS	—	4.25
MnO	7.95	6.87
MgO	0.75	0.88
Na_2S	18.37	14.38
Na_2O	2.94	nil

A series of typical results obtained by the use of the sodium carbonate, limestone, fluorspar mixture, is given in Table IV, and an analysis of the slag formed on the surface of the metal is shown in Table V.

As would be anticipated, the degree of desulphurisation which is attained shows some variation, and it has been observed that greater efficiency is attained with increased temperature of the iron. In spite of these minor variations it can be safely accepted that with pig-iron containing over about 0.125 per cent. of sulphur, one treatment with the sodium carbonate/limestone/spar mixture or plain sodium carbonate will remove from 50 to 75 per cent. of the sulphur content with an average elimination of about 60 per cent.

It is to be noted from the foregoing examples, covering as they do an exceedingly wide range of sulphur content, that the efficiency of the desulphurising mixture increases as the weight of sulphur to be removed increases. In other words, the higher percentages of sulphur are more readily removed than the lower percentages, and while it is clearly demonstrated that the sulphur content of the iron can be successfully reduced even in ranges below 0.100 per cent., yet the lower the sulphur content the greater is the difficulty to remove the same proportion and the less efficient, on the theoretical basis, is the action of the desulphurising agent.

This leads to the conclusion, which has been verified in practice, that the removal of sulphur is effected more completely and economically if carried out in stages rather than in one operation.

Desulphurisation of the Pig-Iron for Steel-Making

In general, the pig-iron as tapped from the blast furnace is carried in liquid form to a hot-metal mixer and maintained fluid until required for transfer to the steel-making furnace. On the Continent and in the U.S.A. this mixer is of the inactive type and is merely a reservoir or container, and no refining of the iron is attempted. In Great Britain, the mixer is normally of the active type, and the pig-iron is often refined to a marked extent during the period of lying in the mixer. In both types of mixer, provided the correct conditions are established and the pig-iron contains over 0.6 to 0.7 per cent. of manganese, there is a considerable elimination of sulphur. With irons of low manganese content most of the sulphur exists as FeS, which is soluble in liquid iron, and no reduction of sulphur can be effected. With a sufficient amount of manganese the major part of the sulphur is combined as MnS. This MnS is insoluble in liquid iron, and when the metal is allowed to stand, either in the ladle or in the mixer, the particles of MnS gradually rise to the surface and form a slag, thereby reducing the sulphur content of the metal. With mixers of the closed type and little circulation of air, this process is limited in extent by the fact that this slag becomes saturated with sulphide and the liquation is slowed down.

It has been found, however, that if a current of air or oxidising gas is passed over the surface of the slag, the manganese sulphide is oxidised to manganese oxide and the sulphur escapes as sulphur dioxide to the atmosphere. By this action the concentration of MnS in the slag is maintained at a minimum and the process of sulphur migration proceeds until upwards of 50 per cent. of the sulphur is eliminated from the iron. The degree of desulphurisation effected in practice varies with the temperature of the iron, the length of time that the iron lies in the mixer, the manganese content and the maintenance of the oxidising atmosphere.

Examples of this desulphurisation in the mixer are given in Table VI from the daily records of a mixer, of the inactive type, through which 1,100 tons of pig-iron pass per day. A typical analysis of the slag formed on the surface of the metal is as follows:—SiO_2, 39.6 per cent.; Al_2O_3, 0.86; FeO, 2.3; MnO, 30.31; CaO, 12.6;

TABLE VI.—*Desulphurisation in Mixer.*

Pig-iron to mixer.			Hot metal from mixer.			Elimination of S.	
Si.	S.	Mn.	Si.	S.	Mn.	Actual.	Proportion.
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
0.55	0.195	0.54	0.56	0.140	0.42	0.055	27
0.78	0.194	0.62	0.75	0.111	0.59	0.083	40
0.78	0.130	0.74	0.70	0.075	0.90	0.055	42
0.69	0.090	0.91	0.66	0.085	0.85	0.006	7
0.78	0.089	1.26	0.77	0.076	0.99	0.013	15

(*Continued on page* 204.)

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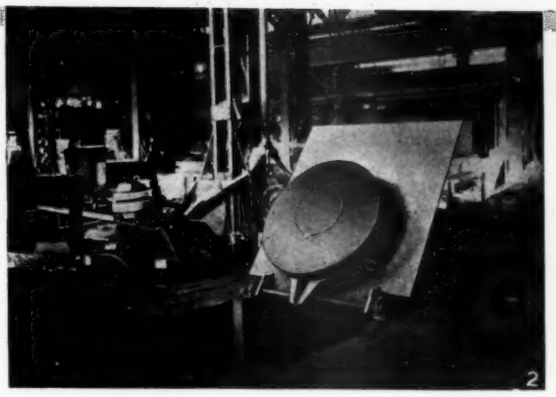

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MgO, 1.88; TiO_2, 3.7; Na_2O, 6.17; S, 1.15; P, trace; and fluorine, trace.

The complete process for the elimination of excess sulphur as at present developed may consist, if necessary, of four distinct stages. First, the pig-iron as tapped from the blast furnace is treated with a predetermined quantity of the sodium carbonate or the desulphurising mixture in the ladle, and the reaction is allowed to proceed while the iron is being transported to the hot-metal mixer. In this stage from 50 to 70 per cent. of the sulphur is removed.

TABLE VII.—*Examples of Desulphurisation from Pig-iron to Steel Ingot.*
(Average Daily Analyses.)

	Pig-iron.						Hot metal.				Sulphur in ingots. Per cent.		
	From blast furnaces. Per cent.			To mixer. Per cent.			From mixer. Per cent.			To Bessemer converters. Per cent.			
	Si.	S.	Mn.	Si.	S.	Mn.	Si.	S.	Mn.	S.	Maximum.	Minimum.	Average.
A.	0.98	0.410	0.75	0.78	0.194	0.62	0.75	0.111	0.59	0.084	0.054	0.030	0.042
B.	0.79	0.382	0.60	0.63	0.161	0.52	0.62	0.130	0.52	0.065	0.054	0.030	0.042
C.	0.97	0.331	0.78	0.78	0.130	0.74	0.70	0.075	0.90	0.075	0.052	0.023	0.035
D.	0.99	0.273	1.02	0.69	0.090	0.91	0.66	0.085	0.85	0.075	0.049	0.027	0.036
E.	0.73	0.256	0.85	0.58	0.091	0.81	0.48	0.091	0.66	0.087	0.050	0.031	0.041
F.	0.92	0.255	0.82	0.72	0.095	0.79	0.64	0.073	0.80	0.056	0.050	0.027	0.037
G.	1.03	0.217	0.82	0.85	0.079	0.74	0.65	0.073	0.66	0.066	0.050	0.025	0.038

At the mixer, the slag formed is skimmed from the surface of the metal to prevent attack on the mixer lining, the pig-iron is transferred to the mixer and allowed to stand under an oxidising atmosphere. If necessary, ferro-manganese is also added to the mixer to give the metal the desired manganese content. According to the length of time that the metal remains in the mixer, from 10 to 40 per cent. of the sulphur content is eliminated.

The hot metal in the mixer is sampled regularly, and if the sulphur content is still higher than specification, or if a steel of special low-sulphur content is desired, a second treatment with sodium carbonate or the desulphurising mixture is given as the hot metal is running from the mixer into the ladle for transfer to the steel furnace. Again, up to 50 per cent. of the residual sulphur can be eliminated. Finally, the sulphur content of the steel can be still further reduced by the methods normally employed during the steel-making process.

Typical examples, taken over a wide range of sulphur variation and showing the extent of the field to which this process can be applied, are given in Table VII, and the degree of desulphurisation at various stages of the operation are shown in Table VIII.

These examples show not only the complete manner in which steel of any desired sulphur specification can be made from pig-iron irrespective of the original content of sulphur in the iron, but also illustrate the extreme flexibility of the process of desulphurisation with respect to both the quantity of sulphur to be removed and the different stages at which this excess sulphur may be eliminated.

Conclusion

The combination of the method of operation of the blast furnace wherein the fluxes are added to the burden in such proportions as will give a slag of minimum melting point and viscosity without regard to the sulphur content of the iron and the excess of sulphur contained in the pig-iron is removed by subsequent treatment with desulphurising agents, has now been fully developed and established on a commercial basis. It has been demonstrated that under these conditions, steel of any desired specification is produced while the rate of production, coke consumption and operating costs are improved. Large tonnages of pig-iron and steel, well over half-a-million tons, have been manufactured to date under this combination of processes with results satisfactory from the point of view of both quality and cost, and patent protection of the fundamental principles has been granted, or applied for.

In view of the accumulated experience of the two firms, an agreement has been entered into between Messrs. H. A. Brassert & Company, Limited, and Imperial Chemical Industries, Limited, for the development of this new process of acid burdening of blast furnaces and the subsequent desulphurisation of the iron and steel. The combined technical-service staffs of the two firms will be available to the industry to assist in the introduction of the technique required for operating furnaces by this method.

It will be abundantly clear to all engaged in the iron and steel trades that at the present time, a process which not only increases production and reduces costs, but also makes available sources of raw material not normally suitable, is of widest possible interest and importance.

TABLE VIII.—*Percentage Desulphurisation in Stages of Operation.*

Test.	In blast-furnace ladle. Per cent.		In mixer. Per cent.		In transfer ladle. Per cent.		In steel furnace. Per cent.	
	Operation.	Cumulative.	Operation.	Cumulative.	Operation.	Cumulative.	Operation.	Cumulative.
A.	52.7	—	42.7	72.9	24.3	79.5	50.0	89.7
B.	57.8	—	19.2	65.9	50.0	83.0	35.3	89.0
C.	60.7	—	42.3	77.3	nil	77.3	53.3	89.1
D.	67.0	—	5.5	68.8	11.7	72.5	52.0	86.8
E.	64.4	—	nil	64.4	4.4	66.0	52.8	83.9
F.	62.7	—	22.1	71.3	23.3	78.0	33.9	85.4
G.	63.6	—	7.6	66.4	9.6	70.0	42.4	82.4

Electricity Returns

The total amount of electricity generated at 442 stations in 1936 was 21,649,693,157 units, an increase of 13.98 per cent. on the corresponding figures for 1935, according to returns made to the Electricity Commissioners. The amount of coal and coke consumed increased by 10.5 per cent. to 13,791,560 tons, and fuel oil by 1.2 per cent. to 24,043 tons.

Metallurgy and the Aero Engine

(*Concluded from page* 200.)

Cast iron contains minute particles of free carbon in the form of graphite. The methods of X-ray and electron diffraction have shown that the carbon atoms in graphite are built up together in the form of thin flat plates or flakes, and that when a smooth surface of cast iron is polished, this has the effect of bringing out the occluded graphite flakes and of spreading them out over the iron surface so that their slip planes are parallel to it. In this way they act as a lubricating layer protecting the iron from abrasion. It is this unique power of forming a good bearing surface which keeps cast iron supreme as a piston ring material in spite of its being entirely unsuitable from almost every other point of view. It has poor elastic properties, it is brittle, and it conducts heat badly, but the essential thing is that a piston ring must continue to rub without seizure under conditions in which satisfactory lubrication is impossible, and therefore engineers put up with the shortcomings of cast iron because of its peculiar virtue in this one respect.

Piston Ring Development

A piston ring may seem an insignificant trifle in the whole design, but it is, perhaps, the most critical element in the piston. More money has been spent in bringing the modern piston ring to its present imperfect stage of development than on any other single element of the design, and the problem is still one in which there is great scope for the metallurgical physicist. The reason why piston ring development is so expensive is that nothing short of prolonged tests at nearly full load in the actual engine will find its weakness, and the failure, if it comes, may be the starting point of widespread damage.

Engine development is almost synonymous with development of the material the engine is made of; an improved fuel may allow a higher supercharge, but full use cannot be made of it without parallel improvements in a hundred other directions to meet the more severe conditions of heat flow and mechanical loading. The new problems range from the call for a steel with a tensile strength of 150 tons per sq. in. to the need for a more stable lubricating oil or an improved insulator for the sparking plug; but undoubtedly it is the metallurgist who must chiefly and always be at hand to advise, and he in his turn must be ready to listen to what the pure physicist can tell him.

The importance of a knowledge of surface conditions and the ultimate structure of metal surfaces in terms of atomic arrangement has been stressed because there lies the necessary line of advance in the crucial problem of rubbing without seizure. Hitherto engineers have been able to rely safely upon an oil film to keep down the extent of the metallic contacts, but as the temperatures of the working surfaces increase the viscosity of the oil gives less and less protection, and the nature of the metal surfaces will play a more and more important *rôle* in the avoidance of seizure.

The line taken by the engineer to-day is to make use of one of the recognised methods, of which there are several, of producing a hardened surface; but does one know accurately, in terms of the ultimate atomic structure, why one surface is hard and another soft? If the physicist would indicate that, engineers might make a big step towards the goal of the perfect piston ring and the unseizable-bearing surface, and there are plenty of other problems which will perplex engineers until the physicist discovers the ultimate nature of the materials with which they work.

AN ORDER FOR 22 electric locomotives for service on the Natal Railway has been placed with the Metropolitan-Vickers Electrical Company, Limited, by the South African Government.

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The Week's News in Brief

Trade Talk

THE TEAM VALLEY TRADING ESTATE at Gateshead-on-Tyne inaugurated its first internal railway service over part of its 5-mile track last Friday.

R. Y. PICKERING & COMPANY, LIMITED, Wishaw, have obtained a large part of the orders for 1,150 new ore and goods wagons placed by the L.M.S. Railway Company.

CANADIAN PIG-IRON PRODUCTION increased by 25 per cent. during the first half of 1937. The output reached 424,000 tons. Steel-ingot production, at 713,000 tons, represented an advance of 23 per cent.

BABCOCK & WILCOX, LIMITED, of London, have been awarded the contract for boiler plant in connection with the £300,000 scheme for extensions to the Darlington electricity generating station.

SIXTY-FOUR MEMBERS of the sales and design staff of David Brown & Sons (Hudd.), Limited, Huddersfield, spent an enjoyable day at Blackpool last Saturday. Travelling by coach, they had lunch at Preston and tea in the Spanish Hall at the Winter Gardens, Blackpool.

MR. K. BADER, of Westmoreland Road, London, N.W.9, has developed and placed on the market a paint known by the trade name of "Lucifer," which is stated to withstand 1,650 deg. C. without losing its colour. As a refractory coating for bricks, this property should be useful.

MORE THAN 4,000 engineering workers employed by Imperial Chemical Industries, Limited, will receive a 6¼ per cent. bonus as from September 6, as a result of a wages agreement reached last week between I.C.I. and the engineering unions. The bonus will involve wage increases varying from 4s. 5d. to 5s. 8d. a week.

BLACKSTONE & COMPANY, LIMITED, of Stamford, Lincs, who this year celebrate their centenary, now employ the record number of over 1,100 men. Some sixteen months ago Blackstone's were taken over by R. A. Lister & Company, Limited, of Dursley, Glos, and many far-reaching changes have since been made in the organisation.

SHORT BROS., LIMITED, of Sunderland, have secured an order for a 9,800-ton ship for Greek owners, and S. P. Austin & Son, Limited, also of Sunderland, are to build a 2,300-ton collier for the London Power Company. The North-Eastern Marine Engineering Company, Limited, will supply the engines for both vessels.

MEMBERS OF THE Electrical Association for Women, attending the Association's summer school in Glasgow, last week paid a visit to Carron Company's works at Falkirk. In the electrical heater and cooker department they were shown all the stages of manufacture, as well as the enamelling process. The party was afterwards entertained to tea by Mr. George Pate (general manager).

RUSTON & HORNSBY, LIMITED, of Lincoln and Grantham, are to discontinue the manufacture of agricultural implements at their Grantham works as soon as possible after September 30. This step has been made necessary by the increasing demand for the various types of engines, boilers and pumps which the company manufacture. Spare parts for their agricultural implements will, however, continue to be available.

A LARGE EXTENSION is to be made at the factory of the Singer Manufacturing Company, Limited, Kilbowie. Two years ago, when the firm transferred machinery from Clydebank to new factories in Italy and France, it was expected that there would be a permanent reduction in output. The volume of orders now being received, however, is such that the factory is working to capacity, and many of the workers are on extensive overtime.

PENISTONE, which was faced with serious unemployment when the steelworks there of Cammell, Laird & Company were closed down during the depression, is again prospering and there are very few unemployed apart from those who are too old for modern industry. Activity rules at the works of David Brown & Sons, gear-cutters, which occupy part of the old Cammell, Laird premises. At the present time 250 new houses are being erected in Penistone.

DEVELOPMENTS OF SOME IMPORTANCE to the iron and steel industry are foreshadowed in the announcement of an agreement concluded between Imperial Chemical Industries Limited, and H. A. Brassert & Company, Limited. The latter company, it may be remembered, were the originators of a novel process of blast-furnace operation which, by making possible an increased output of better quality pig-iron with considerable coke saving, represents one of the most important advances in ferrous metallurgy of recent years. It is already in successful operation in Great Britain, America and Germany. Imperial Chemical Industries, Limited, have had unique experience in the development of the sodium-carbonate process for the desulphurisation of iron and steel—an operation which in a modified form is an essential feature of the Brassert process. The object of the new agreement for the joint development of the Brassert process is to make the technical resources of both companies available to firms wishing to operate their blast furnaces according to the new principle. A demonstration of the new process will be given on the joint stand of the two companies at the Foundry Trades' Exhibition which opens at Olympia next Thursday. This will take the form of a comparative illustration, by means of a system of lighting, of the results achieved by the old and new methods of operation in a model blast furnace.

Personal

MR. LEONARD TURNER, recently of Samuel Tyzack & Company, Limited, Monkwearmouth, Sunderland, has been appointed assistant general manager to the Midland Iron Company, Limited, Rotherham, to assist Mr. A. Corker, director and general manager.

MR. ALEXANDER BELCH, having been appointed deputy chairman of the Shipbuilding Conference, has resigned his appointment as secretary of the Shipbuilding Employers' Federation. Mr. William Watson has been appointed assistant secretary of the Federation, no appointment as secretary having yet been made.

Obituary

MR. JAMES M'INTYRE, of North Street, Dumbarton, for 55 years a moulder in the Lennox Foundry, has died at the age of 86.

MR. CHARLTON THEW, who retired in June from the post of works manager at the marine engineering works of R. & W. Hawthorn Leslie & Company, Limited, died at Newcastle-upon-Tyne on August 30. He was 60 years of age.

MR. ADAM LATIMER ARMSTRONG, a former Mayor of Tynemouth, died at Monkseaton on August 26, at the age of 74. He was formerly connected with Smith's Dock Company, Limited, and was well known in engineering and shipbuilding circles in the North of England.

WE REGRET TO RECORD the death last Thursday of Mr. George Herbert Oxley, managing director of George Oxley & Sons, Limited, Vulcan Foundry, Attercliffe Road, Sheffield. Mr. Oxley was 70 years old, and had been connected with his firm for more than half a century. He was a prominent member of the Sheffield Branch of the Institute of British Foundrymen, which he joined in 1921 and over which his son, Mr. G. L. Oxley, presided with distinction a few years ago. At his funeral, last Monday, many associations and firms connected with the foundry industry, and particularly ingot-mould making, were represented.

New Companies

(From the Register compiled by Jordan & Sons, Limited, Company Registration Agents, 116 to 118, Chancery Lane, London, W.C.2.)

Aluminium Products, Limited, 4, Holloway Road, West Bromwich, Staffs.—Capital, £500.

Cords Piston Ring Company, Limited.—Capital, £1,000. Subscriber: W. E. C. Norris, 2, Bond Court, Walbrook, London, E.C.4.

Midland Monolithic Furnace Lining Company, Limited.—Capital, £4,000. Directors: W. F. Pyatt, 33, Humberstone Road, Leicester; F. A. Chapman.

Company Meetings

Brightside Foundry & Engineering Company, Limited

The annual meeting of the Brightside Foundry & Engineering Company, Limited, was held in Sheffield last week. MR. FRED W. FIRTH (chairman), who presided, said that the accounts showed an excellent year's working. Additions had been made in their plant and machinery account, representing cost to date of installing further foundry plant and new machine tools, and already considerable benefit had accrued. While export trade had not improved as much as they would have liked, conditions in this country during the last year had been much better than for a long time past, and they had been able, due to their policy over the last few years, in preparing for these better times, to take full advantage of the increased amount of business which had been available. The year under review had been a record one in the history of the firm both with regard to manufactured tonnage and turnover, the latter exceeding £1,000,000, approximately seven times the amount of their capital. The foundries and engineering departments had been working to full capacity throughout the year. The heavy foundry had again manufactured a number of large castings, each weighing considerably over 100 tons, and they had orders for similar castings on their books extending well into next year. Their trade in chilled, grain, and alloy rolls had expanded and they had put several new types of roll on the market with success. They had also carried out many complete rolling mill installations, both for steelworks and the non-ferrous industry, and had important contracts going through the shops at present. Their machinery for the manufacture of refractory materials continued in good demand.

Braithwaite & Company, Engineers, Limited

The annual meeting of Braithwaite & Company, Engineers, Limited, was held in London on September 1. MR. J. H. HUMPHRYES (chairman), who presided, said that the aggregate value of orders on the company's books to-day was in the neighbourhood of £1,500,000. The company had secured an important contract in Turkey which was now being carried out, and would continue to take special steps to maintain and increase their connections overseas. The shortage of steel and uncertainty as to future deliveries made it especially difficult at this time to negotiate for large overseas contracts; and it was a question whether some portion of the British steel which was now being exported in the form of semi-manufactured goods should not be earmarked for the use of companies who were quoting in overseas markets for bridges, structures and other such fully manufactured articles. They were, of course, indirectly interested in orders which were on the books of their subsidiary, Braithwaite & Company (India), Limited, and of their associate, the Braithwaite Burn & Jessop Construction Company, Limited; so that was it not an over-statement to say that, directly and indirectly, they were interested in orders of an aggregate value of considerably over £2,000,000.

Company Reports

Triplex Foundry, Limited.—Interim dividend of 2½ per cent.

Quirk, Barton & Company, Limited.—Interim dividend of 2½ per cent.

Ransome & Marles Bearing Company, Limited.—Final dividend of 12½ per cent., making 20 per cent. for the year ended June 30. Directors also propose to distribute a bonus of one share for every four shares held on October 8.

General Refractories, Limited.—Statement of the combined assets and liabilities of the subsidiaries shows at March 31 a general surplus of £608,025, a reserve of £296,874 against depreciation, and a surplus of £141,758 over the parent company's own book figures.

Forthcoming Events

SEPTEMBER 16 TO OCTOBER 2.

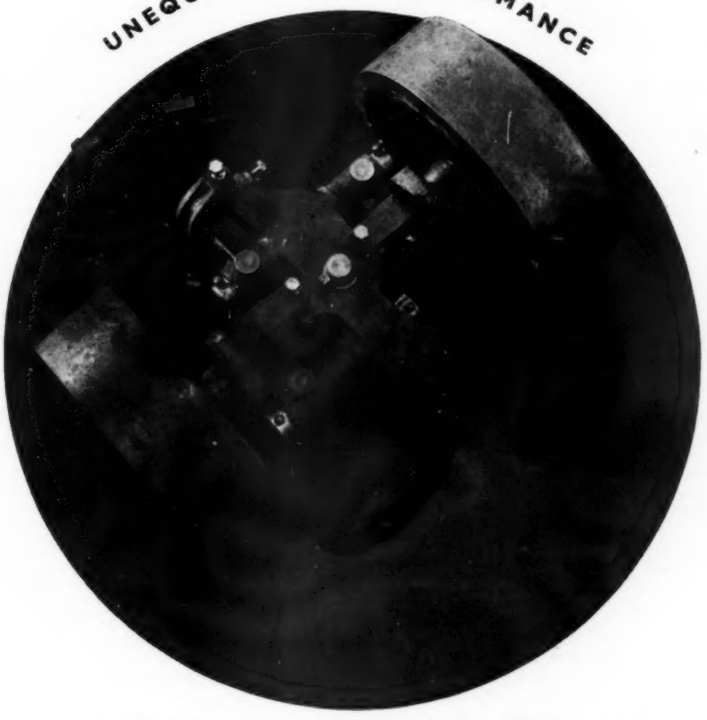
Engineering and Marine Exhibition:—Incorporating the Foundry Trades' Exhibition and the Welding Exhibition, at Olympia, London, W.14.

SEPTEMBER 14 TO 17.

Iron and Steel Institute.—Autumn Meeting in Middlesbrough.

THE "COGGON" RAPID INTENSIVE SAND MIXING MACHINE

UNEQUALLED IN PERFORMANCE



The above is a Standard 72-inch diameter Machine.

We extend a hearty invitation to all interested in Foundry Mechanism to visit us. Our demonstration units will convince. Sound Engineering products, maximum output of thoroughly prepared facing and moulding sands. Low power costs.

●

Coggon Foundry Equipment Ltd.

Shay Lane, Ovenden,

HALIFAX, YORKS.

Telegrams: "Coggon, Halifax" Telephone: 2423

Raw Material Markets

Consuming industries are working to capacity, and now that holiday influences are tending to vanish, the pressure for deliveries of iron and steel will be much increased.

Pig-Iron

MIDDLESBROUGH.—Pig-iron shipments from the Tees have been on a larger scale during the holiday period, makers deeming it advisable to take every advantage of the temporary quietude. August shipments totalled 10,120 tons, against only 4,967 tons in July. Coastwise shipments in August accounted for only 2,135 tons, against 7,985 tons sent abroad. As far as home trade is concerned, every effort is being made by consumers to place new business, but the question of delivery is most uncertain. Steelmakers continue to dominate the market, and foundries receive only scant attention. No. 3 Cleveland G.M.B. is quoted at 101s. in the Middlesbrough district, 104s. in Falkirk, and 107s. on the Clyde.

The hematite position has shown a definite improvement. With an increase in production, makers have been able to reduce, to a small extent, their considerable delivery arrears, both at home and abroad. The demand is expected to be still heavier in the autumn. Ordinary mixed numbers are quoted in the North-East Coast area at 122s. 6d. per ton, less 5s. rebate, in Sheffield at 128s. and in Birmingham at 133s. 6d.

LANCASHIRE.—Most consumers in this area are relying solely on current deliveries for their requirements, as stocks are rarely to be found. In many cases users do not receive the tonnage necessary to enable them to maintain their plants at full-capacity working. Trade generally is concerned only with the replacement of contracts, and even this is not always possible.

MIDLANDS.—Generally, the supply position is more satisfactory and deliveries are heavier. The temporary lull at the light-castings foundries is still noticeable, but activity is expected to increase in the early autumn. Prices are unchanged and there is unlikely to be any alteration in quotations before next year. Minimum prices are 103s. 6d. for No. 3 Northants and 106s. for No. 3 Derbyshire, Lincolnshire or North Staffordshire, including delivery to Birmingham and Black Country stations. The demand for special-quality iron is well maintained. Low-phosphorus iron is quoted at from £6 10s. to £7 5s., while Continental No. 3 foundry iron is at £6 5s. to £6 10s. per ton, including delivery to this district. Users of hematite are unable to procure the tonnage they would like, and deliveries are having still to be rationed very carefully. The controlled prices, which apply to the end of the year, are £6 13s. 6d. for East Coast No. 3 and £6 14s. 6d. for West Coast mixed numbers, delivered local stations, with 1s. 6d. extra if delivered into works.

SCOTLAND.—Consumers in this area have to be content with whatever tonnage the makers can despatch against contracts. No. 1 foundry is quoted at 115s. 6d. and No. 3 at 113s., f.o.t. furnaces. In some cases higher figures have been paid. Following reductions in the prices of Continental iron, imports have been more substantial. No. 3 Cleveland is quoted at 104s. f.o.t. Falkirk and 107s. f.o.t. Glasgow, but no iron is offered. Imports of basic iron have relieved the position at the steelworks to some extent. Hematite mixed numbers are quoted at 123s., Scottish basic at 107s. 6d., and English and Indian basic at 100s., all less 5s. rebate, delivered steelworks.

Coke

Some Durham ovens are now willing to accept orders for the first half of 1938; such business is charged at 1s. 6d. per ton over and above current figures. For delivery to Birmingham and district, best Durham coke is quoted at a minimum of 51s. 6d., while Welsh coke varies from 52s. 6d. to 69s. per ton, according to quality.

Steel

Since the beginning of the month there has been a sharp revival in the activity of the steel trade. In practically all departments consumers are pressing to obtain supplies, and in many cases would be prepared to place orders for execution well into next year. It is by no means easy, however, to find manufacturers in a position to accept new business, owing to the heavy tonnages already upon their books and to a natural disinclination to undertake far forward commitments. In the semi-finished steel section of the market, the demand remains in excess of supply, but the conditions are better than those ruling a few months ago. More regular supplies are being received from the British producers and some improvement is noticeable in the imports of Continental steel. Great activity prevails in the finished steel section of the market, and the steelmakers are concentrating upon supplying urgently-required material. There is still great difficulty in placing new business for delivery this year. The export demand appears to be broadening, but only a proportion can be accepted, owing to the necessity of meeting the heavy home trade requirements.

Scrap

Conditions on the scrap iron and steel market remain very firm. Undoubtedly, the drive to expand the output of steel will result in a greatly-increased demand for scrap, and imports may have still further to be increased. Prices are firm, and merchants have no difficulty in disposing of all they can procure.

Metals

A protracted conflict in the East would eventually result in substantial increases in metal prices, and possibly an acute shortage of supplies. Japan has taken up large tonnages of copper during the past few months, and inquiries from that source are still in the market both in this country and in the United States. The desire to buy lead has also been shown by Japan, and it is suggested that the decision to give precedence to material for munitions in the import quotas may facilitate sales. The possibility of tin supplies from China being curtailed is being given consideration.

Copper.—There is little change to report in the condition of this market, which remains dull. Prospects are satisfactory, however, and an increase in trade demand is shortly anticipated. Business in the United States is confined largely to the requirements of working-up plant associated with producers.

Metal Exchange quotations were as follow :—

Cash.—Thursday, £54 13s. 9d. to £54 15s.; Friday, £54 10s. to £54 12s. 6d.; Monday, £55 2s. 6d. to £55 3s. 9d.; Tuesday, £56 to £56 1s. 3d.; Wednesday, £56 11s. 3d. to £56 12s. 6d.

Three Months.—Thursday, £54 18s. 9d. to £55; Friday, £54 15s. to £54 16s. 3d.; Monday, £55 7s. 6d. to £55 8s. 9d.; Tuesday, £56 2s. 6d. to £56 3s. 9d.; Wednesday, £56 11s. 3d. to £56 12s. 6d.

Tin.—According to statistics compiled by Mr. W. H. Gartsen (Henry Rogers, Sons & Company), the total visible supply of tin at the end of August was 20,167 tons, as compared with 20,150 tons on July 31. The carry-over in the Straits Settlements was 3,332 tons on August 31, against 3,610 tons on July 31, while the corresponding figures for the carry-over at the Arnhem (Holland) smelter were 1,665 and 1,282 tons. The increase of 122 tons on the month was somewhat surprising. While it is generally accepted that America is under-bought, there is little indication as yet of any substantial buying movement from consumers. The question of export quotas for the fourth quarter was scheduled to come up for consideration at the meeting of the International Tin Committee in Paris to-day (Thursday). It is likely also that discussion will take place on the question of establishing an international reserve stock. The present quota is 110 per cent., and, in view of the fact that none of the countries participating in the restriction scheme was able to produce its quota, a reduction must not be left out of account. On the other hand, the Committee may be influenced to maintain the present quota by other factors, such as armament requirements or probably reduced tin exports by China.

Official quotations were as follow :—

Cash.—Thursday, £259 to £259 10s.; Friday, £260 to £260 5s.; Monday, £260 10s. to £261; Tuesday, £260 10s. to £261; Wednesday, £260 10s. to £261.

Three Months.—Thursday, £258 10s. to £258 15s.; Friday, £259 to £259 5s.; Monday, £259 10s. to £259 15s.; Tuesday, £259 10s. to £259 15s.; Wednesday, £259 10s. to £259 15s.

Spelter.—Little interest has been shown by American consumers in the London market during the past week, and the tone remains quiet. The outlook is quite satisfactory, as the undertone of the market continues to be strong. The acute shortage of metal in the United States is maintained.

Daily market prices :—

Ordinary.—Thursday, £22 8s. 9d.; Friday, £22 8s. 9d.; Monday, £22 13s. 9d.; Tuesday, £22 18s. 9d.; Wednesday, £23 3s. 9d.

Lead.—Pipe and sheet makers are active consumers of lead, and inquiries are on a good scale from these sources of consumption. Lead output in July, according to the American Bureau of Metal Statistics, totalled 155,800 short tons, against 147,200 tons in June. Spanish production is included in the foregoing figures.

Day-to-day quotations :—

Soft Foreign (Prompt).—Thursday, £21 13s. 9d.; Friday, £21 12s. 6d.; Monday, £21 15s.; Tuesday, £21 17s. 6d.; Wednesday, £22 6s. 3d.

Scrap.—The demand for non-ferrous metal scrap is still at a low ebb. Heavy tonnages are expected to change hands when consumers embark on their autumn programme. Prices still display a downward trend.

Approximate selling prices for old metal :—New aluminium cuttings, £82; rolled, £67; cast, £43; foil, £94 to £98. Copper, £50 to £54; braziery, £47 to £48. Brass (clean), £31 to £33. Zinc, £15. Lead, £20. Gunmetal, £49 to £51.

Contracts Open

Darlington, September 16.—Cast-iron pipes from 2 in. to 6 in. dia., for the Durham County Water Board. Mr. W. Read Ward, clerk, 77, Northgate, Darlington.

Brisbane, October 28.—Heat-treatment furnaces, core-sand mixer, core-making machine, 20-ton overhead electric travelling crane, travelling electric hoist, lathes, etc., for the Queensland Railway Workshops. The Department of Overseas Trade. (Reference T. 18,954/37.)

THE NORTH EASTERN MARINE ENGINEERING COMPANY, LIMITED, of Wallsend, has secured a contract to supply triple-expansion engines for two 4,000-ton oil tankers which are to be constructed abroad for the Standard Oil Company, New York.

MAY WE
VITREOUS ENAMEL
YOUR CASTINGS ?
OUR PRICES ARE REASONABLE.
WHYMAN'S FOUNDRY CO. LTD., WARRINGTON.

SUPERIOR SILICA BRICKS
FINE SILICA CEMENT.
TRADE MARK—R. DINAS.
SMARTS DINAS SILICA BRICK CO. LTD., KIDWELLY

WE CORDIALLY INVITE YOU TO

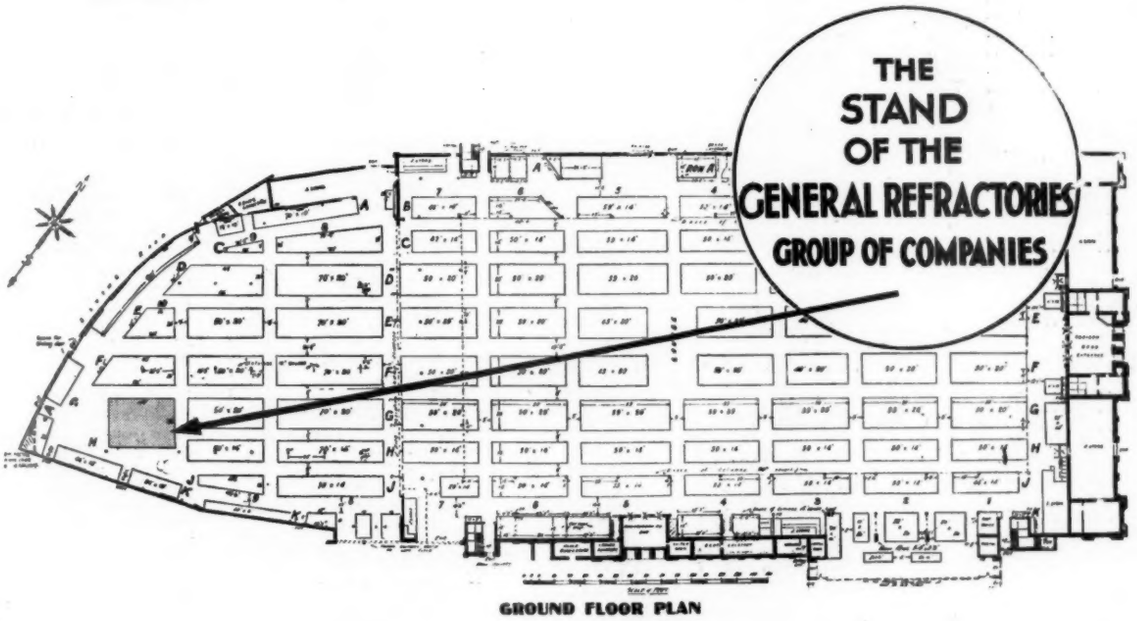
VISIT OUR STAND

AT THE

FOUNDRY TRADES EXHIBITION

No. 21. ROW G.

GROUND FLOOR



GROUND FLOOR PLAN

THERE WILL BE SPECIAL DISPLAYS OF:

Moulding Sands, Basic Refractories, Insulating Materials, Firebricks, Silica Bricks, Cements and Plastic Refractories.

GENERAL REFRACTORIES LIMITED

Head Office:

GENEFAX HOUSE, SHEFFIELD

Telephone: 31113 (6 lines) Telegrams: "Genefax, Sheffield"

London Office:

RUSSELL HOUSE, ADLEPHI, W.C.2

Telephone: Temple Bar 3511 Telegrams: "Genefax, Rand, London"

Manufacturers of heat resisting and heat insulating materials of every description

RAW MATERIALS—PRICE LIST

(Wednesday, September 8, 1937)

COPPER

	£ s. d.
Standard cash	56 11 3
Three months	56 11 3
Electrolytic	62 5 0
Tough	61 11 3
Best selected	62 1 3
Sheets	91 11 3
India	73 6 3
Wire bars	63 6 3
Ingot bars	63 6 3
H.C. wire rods	66 16 3
Off. av. cash, August	57 3 10¼
Do., 3 mths., August	57 7 1½
Do., Sttlmnt., August	57 3 9½
Do., Electro, August	64 1 8
Do., B.S., August	63 16 4½
Do., wire bars, August	64 11 5½
Solid drawn tubes	14¼d.
Brazed tubes	14½d.
Wire	10d.

BRASS

Solid drawn tubes	12⅜d.
Brazed tubes	14⅜d.
Rods, drawn	11½d.
Rods, extd. or rlld.	7½d.
Sheets to 10 w.g.	10½d.
Wire	9⅝d.
Rolled metal	9½d.
Yellow metal rods	7½d.

TIN

	£ s. d.
Standard cash	260 10 0
Three months	259 10 0
English	260 10 0
Bars	262 10 0
Straits	263 10 0
Eastern	262 10 0
Banca (nom.)	—
Off. av. cash, August	264 15 1½
Do., 3 mths., August	263 0 10½
Do., Sttlmt., August	264 15 5½

SPELTER

	£ s. d.
Ordinary	23 3 9
Remelted	19 15 0
Hard	19 0 0
Electro, 99.9	25 16 3
English	24 0 0
India	19 15 0
Zinc dust	29 0 0
Zinc ashes	7 10 0
Off. aver., August	24 4 3 17/32
Aver. spot, August	24 2 9 7/16

LEAD

	£ s. d.
Soft foreign, ppt.	22 6 3
Empire (nom.)	22 13 9
English	24 10 0
Off. aver., August	22 12 9 1/32
Aver. spot, August	22 12 1 5/16

ALUMINIUM

Ingots	£100 to £105
Wire	1/3 to 1/4 lb.
Sheet and foil	1/2 to 1/4 lb.

ZINC SHEETS, &c.

	£ s. d.
Zinc sheets, English	36 10 0 to 37 0 0
Do., V.M. ex-whse.	36 10 0 to 37 0 0
Rods	30 10 0

ANTIMONY

	£ s. d.
English	92 10 0 to 93 10 0
Chinese, ex-whse. (nom.)	81 0 0
Crude, c.i.f.	45 0 0

QUICKSILVER

	£ s. d.
Quicksilver	13 12 3

FERRO-ALLOYS AND STEEL-MAKING METALS

Ferro-silicon—	
25%	14 10 0
45/50%	12 0 0
75%	17 0 0
Ferro-vanadium—	
35/50%	12/8 lb. Va
Ferro-molybdenum—	
70/75% carbon-free	4/9 lb. Mo.
Ferro-titanium—	
20/25% carbon-free	9d. lb.
Ferro-phosphorus, 20/25%	£21 to £22
Ferro-tungsten—	
80/85%	8/6 to 9/6 lb.
Tungsten metal powder—	
98/99%	8/7½ to 9/7½ lb.
Ferro-chrome—	
2/4% car.	34 15 0
4/6% car.	24 5 0
6/8% car.	24 0 0
8/10% car.	24 0 0
Ferro-chrome—	
Max. 2% car.	36 0 0
Max. 1% car.	38 5 0
Max. 0.5% car.	41 0 0
70% carbon-free	10d. lb.
Nickel—99.5/100%	£180 to £185
"F" nickel shot	£165 0 0
Ferro-cobalt, 98/99%	8/6 to 8/9 lb.
Metallic chromium—	
96/98%	2/5 lb.
Ferro-manganese—	
76/80% loose	£18 15 0 to 19 5 0
76/80% packed	£19 15 0 to 20 5 0
76/80% export	£22 0 0
Metallic manganese—	
94/96% carbon-free	1/3 lb.

Per ton unless otherwise stated, basis 2-ton lots

HIGH-SPEED TOOL STEEL

Finished bars, 14% tungsten	2s. 7d.
Finished bars, 18% tungsten	3s. 6d.

Per lb. net, d/d buyers' works.

Extras—	
Rounds and squares, 3 in. and over	4d. lb.
Rounds and squares, under ½ in. to ¼ in.	3d. lb.
Do., under ¼ in. to 3/16 in.	1/- lb.
Flats, ½ in. × ¼ in. to under 1 in. × ⅛ in.	3d. lb.
Do., under ½ in. × ¼ in.	1/- lb.
Bevels of approved sizes and sections	6d. lb.

Bars cut to length, 10% extra.

SCRAP

	£ s. d.	£ s. d.
South Wales (West)—		
Heavy steel, best	3 7 6	to 3 10 0
Mixed iron and steel	3 5 0	to 3 7 6
Heavy cast iron	3 7 6	to 3 10 0
Good machinery	4 0 0	to 4 5 0
Cleveland—		
Heavy steel, best	3 6 6	to 3 9 0
Steel turnings		2 15 0
Heavy cast iron		4 7 6
Heavy machinery		4 10 0
Midlands—		
Short heavy steel	3 17 6	to 4 0 0
Light cast-iron scrap		3 2 6
Heavy wrought iron	4 0 0	to 4 5 0
Steel turnings		2 5 0
Scotland—		
Heavy steel, best	3 4 6	to 3 7 0
Ordinary cast iron		4 5 0
Cast-iron borings	2 0 0	to 2 2 6
Wrot-iron piling	4 16 0	to 4 17 6
Heavy machinery	4 13 6	to 4 15 0

London—Merchants' buying prices, delivered yard.

	£ s. d.
Copper (clean)	45 0 0
Brass	29 10 0
Lead (less usual draft)	18 10 0
Tea lead	12 10 0
Zinc	15 0 0
New aluminium cuttings	72 0 0
Braziery copper	41 0 0
Gunmetal	44 0 0
Hollow pewter	170 0 0
Shaped black pewter	126 0 0

PIG-IRON

N.E. Coast (d/d Tees-side area)—	
Foundry No. 1	103/6
,, No. 3	101/-
,, No. 4	100/-
Forge No. 4	100/-
Hematite No. 1	123/-*
Hematite M/Nos.	122/6*
N.W. Coast—	
Hem. M/Nos. d/d Glas.	123/-*
,, d/d Birm.	134/6*
Malleable iron d/d Birm.	160/-
Midlands (d/d Birmingham dist.)—	
Staffs No. 4 forge	103/-
,, No. 3 fdry.	106/-
Northants forge	100/6
,, fdry. No. 3	103/6
,, fdry. No. 1	106/6
Derbyshire forge	103/-
,, fdry. No. 3	106/-
,, fdry. No. 1	109/-
Scotland—	
Foundry, No. 1, f.o.t.	115/6
,, No. 3, f.o.t.	113/-
Cleveland No. 3, Glasgow	107/-
,, ,, Falkirk	104/-
Scottish hem. M/Nos. d/d	123/-*
Sheffield (d/d district)—	
Derby forge	100/6
,, fdry. No. 3	103/6
Lincs forge	100/6
,, fdry. No. 3	103/6
W.C. hematite	128/6*
Lancashire (d/d eq. Man.)—	
Derby fdry. No. 3	109/-
Staffs fdry. No. 3	109/-
Northants fdry. No. 3	107/6
Cleveland fdry. No. 3	109/-
Glengarnock, No. 3	137/6
Clyde, No. 3	137/6
Monkland, No. 3	137/6
Summerlee, No. 3	137/6
Eglinton, No. 3	137/6
Gartsherrie, No. 3	137/6
Shotts, No. 3	137/6

* Subject to a rebate of 5s. per ton under certain conditions.

FINISHED IRON AND STEEL

Usual district deliveries.

[A rebate of 15/- per ton for steel sections, plates and joists is obtainable in the home trade under certain conditions.]

Iron—	£ s. d.	£ s. d.
Bars (cr.)	13 5 0	to 13 15 0
Nut and bolt iron	11 12 6	to 12 2 6
Hoops		14 2 6
Marked bars (Staffs) f.o.t.		15 15 0
Gas strip		14 2 6
Bolts and nuts, ¾ in. × 4 in.		17 10 0 and up.
Steel—		
Plates, ship, etc.	11 8 0	to 11 10 6
Boiler plts.	11 18 0	to 12 0 6
Chequer plts.		13 0 6
Angles		11 0 6
Tees		12 0 6
Joists		11 0 6
Rounds and squares, 3 in. to 5½ in.		12 0 6
Rounds under 3 in. to ¼ in. (Untested)		11 9 0
Flats—8 in. wide and over		11 5 6
,, under 8 in. and over 5 in.		11 10 6
Rails, heavy		10 2 6
Fishplates		14 2 6
Hoops (Staffs)		12 4 0
Black sheets, 24g. (4-t. lots)		15 15 0
Galv. cor. shts. (,,)		19 10 0
Galv. flat shts. (,,)		20 0 0
Galv. fencing wire, 8g. plain		20 5 0
Billets, soft, 100-ton lots		7 17 6
Sheet bars		7 15 0
Tin bars		7 15 0

PHOSPHOR BRONZE

	Per lb. basis
Strip	13½d.
Sheet to 10 w.g.	13½d.
Wire	15d.
Rods	16d.
Tubes	20½d.
Castings	16d.

Delivery 3 cwt. free.
10% phos. cop. £33 above B.S.
15% phos. cop £38 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. CLIFFORD & SON, LIMITED.

NICKEL SILVER, &c.

	Per lb.
Ingots for raising	9d. to 1/3
Rolled—	
To 9 in. wide	1/3 to 1/9
To 12 in. wide	1/3½ to 1/9½
To 15 in. wide	1/3½ to 1/9½
To 18 in. wide	1/4 to 1/10
To 21 in. wide	1/4½ to 1/10½
To 25 in. wide	1/5 to 1/11
Ingots for spoons and forks	9d. to 1/5½
Ingots rolled to spoon size	1/- to 1/8½
Wire round—	
to 10g.	1/6½ to 2/1½

with extras according to gauge.
Special 5ths quality turning rods in straight lengths, 1/5½ upwards.

AMERICAN IRON AND STEEL

At Pittsburgh unless otherwise stated.

	Dols.
No. 2 foundry, Phila.	25.76
No. 2 foundry, Valley	24.00
No. 2 foundry, Birm.	20.38
Basic, Valley	23.50
Malleable, Valley	24.00
Grey forge, Valley	23.50
Ferro-mang. 80%, seaboard	102.50
O.-h. rails, h'y, at mill	42.50
Billets	37.00
Sheet bars	37.00
Wire rods	47.00
	Cents.
Iron bars, Chicago	2·40
Steel bars	2.45
Tank plates	2.25
Beams, etc.	2.25
Skelp, grooved steel	2.10
Steel hoops	2.40
Sheets, black, No. 24	3.15
Sheets, galv., No. 24	3.80
Wire nails	2.75
Plain wire	2.90
Barbed wire, galv.	3.40
Tinplates, 100-lb box	$5.35

COKE (at ovens)

Welsh foundry	42/6
,, furnace	37/6
Durham foundry	36/6
,, furnace	35/6
Scottish foundry	42/6
,, furnace	40/-

TINPLATES

f.o.b. Bristol Channel ports.

I.C. cokes	20×14 per box	25/6 to 26/-
,,	28×20 ,,	51/- to 52/-
,,	20×10 ,,	36/6 to 36/9
,,	18¾×14 ,,	26/3 to 26/6
C.W.	20×14 ,,	22/6 to 23/-
,,	28×20 ,,	46/- to 46/6
,,	20×10 ,,	32/- to 32/6
,,	18¾×14 ,,	23/- to 23/6

SWEDISH CHARCOAL IRON & STEEL

Pig-iron	£12 0 0	to £13 0 0
Bars-hammered, basis	£20 0 0	to £22 0 0
Bars and nail-rods, rolled, basis	£19 0 0	to £20 0 0
Blooms	£16 0 0	to £17 0 0
Keg steel	£30 0 0	to £35 0 0
Faggot steel	£20 0 0	to £25 0 0
Bars and rods dead soft st'l	£19 0 0	to £20 0 0

All per English ton, f.o.b. Gothenburg.
[Subject to an exchange basis of Kr. 19.39 to £1.]

DAILY FLUCTUATIONS

Standard Copper (cash)

		£	s.	d.		
Sept.	2 ..	54	13	9	dec.	12/6
,,	3 ..	54	10	0	,,	3/9
,,	6 ..	55	2	6	inc.	12/6
,,	7 ..	56	0	0	,,	17/6
,,	8 ..	56	11	3	,,	11/3

Electrolytic Copper

		£	s.	d		
Sept.	2 ..	60	10	0	dec.	15/-
,,	3 ..	61	0	0	inc.	10/-
,,	6 ..	61	5	0	,,	5/-
,,	7 ..	61	15	0	,,	10/-
,,	8 ..	62	5	0	,,	10/-

Standard Tin (cash)

		£	s.	d.		
Sept.	2 ..	259	0	0	dec.	55/-
,,	3 ..	260	0	0	inc.	20/-
,,	6 ..	260	10	0	,,	10/-
,,	7 ..	260	10	0	No	change
,,	8 ..	260	10	0	,,	,,

Tin (English ingots)

		£	s.	d.		
Sept.	2 ..	259	5	0	dec.	55/-
,,	3 ..	260	0	0	inc.	15/-
,,	6 ..	260	10	0	,,	10/-
,,	7 ..	260	10	0	No	change
,,	8 ..	260	10	0	,,	,,

Spelter (ordinary)

		£	s.	d.		
Sept.	2 ..	22	8	9	dec.	7/6
,,	3 ..	22	8	9	No	change
,,	6 ..	22	13	9	inc.	5/-
,,	7 ..	22	18	9	,,	5/-
,,	8 ..	23	3	9	,,	5/-

Spelter (Electro, 99.9 per cent.)

		£	s.	d.		
Sept.	2 ..	25	2	6	dec.	6/3
,,	3 ..	25	1	3	,,	1/3
,,	6 ..	25	6	3	inc.	5/-
,,	7 ..	25	11	3	,,	5/-
,,	8 ..	25	16	3	,,	5/-

Lead (soft foreign, prompt)

		£	s.	d.		
Sept.	2 ..	21	13	9	dec.	1/3
,,	3 ..	21	12	6	,,	1/3
,,	6 ..	21	15	0	inc.	2/6
,,	7 ..	21	17	6	,,	2/6
,,	8 ..	22	6	3	,,	8/9

Lead (English)

		£	s.	d.		
Sept.	2 ..	23	15	0	No	change
,,	3 ..	23	15	0	,,	,,
,,	6 ..	23	15	0	,,	,,
,,	7 ..	23	15	0	,,	,,
,,	8 ..	24	10	0	inc.	15/-

A COMPARISON OF SCRAP PRICES

Prices of Heavy Steel Scrap (Delivered) in the Principal Districts at the Beginning of Each Month in the Years 1930–1937.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Yearly average.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Scotland—													
1930	3 9 0	3 7 6	3 5 0	3 5 0	3 0 6	2 15 0	2 12 0	2 10 0	2 13 3	2 10 0	2 10 0	3 10 6	3 13 1½
1931	2 7 6	2 7 6	2 5 0	2 5 0	2 0 0	1 17 6	1 17 6	1 17 6	1 17 6	1 15 0	2 0 0	2 10 0	2 17 3½
1932	2 2 6	2 2 6	2 0 0	1 17 6	1 17 6	1 17 6	1 15 0	1 15 0	1 12 6	1 13 0	1 12 6	2 2 6	2 1 0½
1933	1 15 0	1 17 6	1 18 6	1 18 9	1 18 0	1 17 6	1 18 9	2 0 0	2 2 6	2 5 0	2 7 6	1 15 0	1 16 9½
1934	2 8 9	2 14 3	2 13 0	2 12 0	2 10 0	2 10 6	2 10 6	2 11 0	2 10 9	2 10 0	2 8 9	2 0 7½	
1935	2 10 0	2 10 0	2 10 0	2 10 0	2 10 0	2 10 0	2 10 0	2 10 0	2 10 0	2 10 0	2 10 0	2 11 2	
1936	2 12 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 1	
1937	2 17 6	3 2 6	3 6 0	3 5 9	3 5 9	3 5 9	3 5 9	3 5 9	3 5 9	—	—	—	—
North-East Coast—													
1930	3 3 6	3 3 6	3 2 0	3 0 0	2 17 6	2 10 0	2 10 0	2 7 6	2 7 6	2 7 6	2 5 0	2 6 0	2 13 4
1931	2 6 0	2 6 0	2 5 0	2 5 0	2 2 6	2 0 0	1 17 6	1 17 6	1 17 6	1 17 6	1 17 6	2 2 6	2 1 2½
1932	2 0 0	2 0 0	1 15 0	1 15 0	1 15 0	1 15 0	1 15 0	1 15 0	1 15 0	1 12 6	1 15 0	1 17 6	1 15 10
1933	2 0 0	2 0 0	2 5 0	2 0 0	1 15 0	1 17 6	2 2 6	2 2 6	2 3 6	2 5 0	2 7 6	2 7 6	2 2 2
1934	2 10 0	2 16 0	2 10 0	2 7 6	2 7 6	2 10 0	2 9 9	2 10 0	2 10 0	2 10 0	2 11 6	2 11 3	2 10 3½
1935	2 11 6	2 11 9	2 12 0	2 12 0	2 12 6	2 12 6	2 12 6	2 12 6	2 12 6	2 12 6	2 12 6	2 13 9	2 12 4½
1936	2 15 0	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	3 0 0	3 0 0	2 17 8½
1937	3 2 6	3 5 0	3 7 0	3 7 9	3 7 9	3 7 9	3 7 9	3 7 9	3 7 9	—	—	—	—
South Wales—													
1930	3 7 6	3 6 0	3 6 0	3 4 0	3 2 6	2 17 6	2 16 0	2 15 0	2 14 9	2 12 6	2 12 6	2 5 0	2 18 3½
1931	2 5 0	2 7 6	2 7 6	2 7 6	2 5 0	2 2 6	2 0 0	2 0 0	1 18 0	2 2 6	2 5 0	2 7 6	2 4 0
1932	2 6 6	2 6 0	2 5 0	2 2 6	2 2 0	1 19 0	1 17 6	1 18 6	1 18 0	1 18 0	1 17 6	1 18 0	2 0 8½
1933	2 0 0	2 1 6	2 4 0	2 3 6	2 3 6	2 3 0	2 5 0	2 5 0	2 8 0	2 10 0	2 10 0	2 10 0	2 5 3½
1934	2 10 0	2 16 3	2 15 9	2 13 9	2 14 3	2 15 0	2 14 3	2 14 3	2 15 0	2 15 6	2 15 6	2 15 6	2 14 7
1935	2 15 6	2 15 6	2 15 6	2 15 6	2 15 6	2 15 6	2 15 6	2 15 6	2 16 1½	2 17 9	2 19 8	3 1 1½	2 16 2½
1936	3 2 6	3 5 0	3 5 0	3 5 0	3 5 0	3 5 0	3 3 0	3 2 0	3 2 0	3 4 0	3 4 0	3 4 0	3 3 10½
1937	3 5 0	3 10 0	3 10 0	3 8 9	3 8 9	3 8 9	3 8 9	3 8 9	3 8 9	—	—	—	—

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